tances between sections computed, then the elevation can be plotted accurately.

Conclusion

The problem above discussed proves to be important when the photographed objects are mostly round. For the past two years or so photogrammetry has been used in recording the monuments, temples, and tombs of the ancient Egyptians located south of Egypt and north of Sudan which will be inundated by the water rising behind the Aswan High Dam.

The problem as discussed was mostly concerned with columns, yet, it is always met with in other cases such as domes, arches, conical steeples, . . . etc.

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Futuristic Photo Interpretation

DR. ANDREW J. NASH,
Assoc. Professor of Forestry,
School of Forestry,
Univ. of Missouri

Technological advances in the field of photogrammetry have been very rapid during the past few years. There have been improvements in cameras, film and stereoscopic mapping instruments. The use of high-speed digital computers has become quite common in the calculations necessary for lens design and in computing coordinates for mapping. New uses of computers are being tried and tested constantly. The results of these improvements in photogrammetric techniques has meant a greater production in mapping from aerial photographs which are taken with essentially distortion-free lenses.

A question asked in this paper and for which an answer will be attempted is: Has photo interpretation kept pace with the advances in photogrammetric techniques? An unqualified answer would have to be in the negative; but some qualifications are necessary. In the first place, information is being derived from photographs taken by satellites, such as TIROS and SAMOS, which give data on conditions in outer space. The interpretation of space photographs is an entirely new concept in photo interpretation and is one which did not exist a few years ago. Another aspect of photo interpretation which is relatively new is the interpretation of radar displays and of thermal photographic systems using energy transmission in the form of electronic or infrared radiation. Great credit must be given to the imagination and persistence of interpreters confronted with photographic records of this type. There can be very little control in the attitude of the photo station in satellite photography, or of the atmospheric conditions at the time of photography. It is nothing short of amazing to consider the amount of information that can be derived from such photographs and images.

The purpose of this paper is to delve into some of the problems which confront the photo-interpreter of today and to look into the future to see what is in store. Before doing that, however, it would be well to review some of the major contributions to the art of photo interpretation. A glance at recent issues of Photogrammetric Engineering is revealing. In the September 1960 issue, Feder discusses the interpretation of terrain from radar displays and the difficulties involved; in the same issue, Ockert discusses the problems associated with satellite photography and its interpretation. Other pertinent articles may be found by Hoffman (1960), Olson (1960) and by Strees (1961). The ones mentioned are by no means the complete list but have been chosen to illustrate the frequency with which such papers have been appearing. Colwell, in 1959, wrote an excellent paper dealing with the future of photo interpretation and photographic systems. On re-reading his paper today, he would find that many of his predictions for the 25 year period in the future have already come true.

Two further developments in photo interpretation should be mentioned at this point. The first is the use of color film and of color reversal film in the interpretation of data for

the biological and earth sciences. Reference is made to their use in the fields of forest inventory, forest pathology, forest entomology and of geology. Color film using normal rendition of colors has proved very useful in certain aspects of photo interpretation; the color reversal type of film has made even greater impact in the interpretation field. More will be said of these two types of film later.

The second development has taken place fairly recently in the interpretation of forest detail on photographs taken with a 100 mm. or 300 mm. on 70 mm. perforated film. This is comparable to using a 16-inch or 48-inch lens with the normal 9-inch by 9-inch format. According to Seely of the Forest Research Branch, Department of Forestry, Ottawa, Ont. the results are quite encouraging. The main application of this type of photography has been to obtain detailed measurements on trees in winter. There is no reason to believe that this type of photography could not be used to advantage in other regions of the country.

The needs of photo interpreters vary according to the particular task at hand; geologists, foresters, soil scientists, highway engineers and city planners all have different objectives. These objectives will be met if the initial photography is suited to or taken for that specific purpose. Whatever the purpose, the photo interpreter needs information that is timely, complete and accurate. It is not fair to expect adequate photo interpretation from photographs which have been taken for a completely different purpose in mind. Too often, economic considerations dictate the type of aerial photographs which must be used. The result is that only gross measurements can be made, and the resulting information is not sufficient for the accuracy required.

In a recent issue of the *Journal of Forestry*, Avery (1962) determined from a survey of private forest industries that, of those which did use aerial photographs in their work, more than 75% used photographs of a scale of 1:20,000 or 1:15,840. It is conceded that the minimum photo-scale for forestry application should be 1:15,840. A preferable scale would be 1:12,000 for extensive interpretation and 1:7,200 or better for intensive application.

Although it is highly commendable that photo interpreters try to determine data from photographs taken from outer space, scientists in the biological and earth sciences should make a special effort to understand more about our own planet. In order to accomplish this, greater use should be made of large-scale black-and-white photography and of the various types of color film available. Most of us are reluctant to request what are seemingly large sums of money to procure better photographs. The impression that field interpretation and field checking are not very expensive persists, and the use of small-scale photographs is justified on that basis. There is an element of false economy in this; a quick check on salaries of field personnel, travel expense, equipment and supplies will show that field work is definitely an expensive item.

A translation of a paper by Mikhailov (1961) indicates that the greater cost of color pictures is offset by an improvement in the quality of the pictures themselves, improvement of the quality of photo interpretation possible, and by a reduction in the amount of ground work required. He estimates that the cost of field interpretation is three to four times the cost of aerial photography. Russian scientists advocate the use of regular color film and of spectrozonal color film for forestry application. This latter type is comparable to our color reversal film. For geological interpretation, regular color film is advocated because natural color is more suited to the identification of geological features. If, however, vegetation is present which is characteristic of a certain soil or of underlying rock, a spectrozonal type of film may be used to advantage.

In the field of forestry, one technique which has had some limited tests and which shows promise for the future is that of combining large-scale sample photography with small-scale coverage. Such a technique would help to answer the criticism of the high cost of photography. The system would involve the use of an additional camera in the survey plane which would take a series of four or five photographs in short "bursts" at intervals along the flight line. Whereas the small-scale coverage might be at a scale of 1:15,840 or 1:20,000, the large-scale sample photography might be at a scale of 1:1,200. Of course, in this system the camera taking the large-scale photographs would have to have its own intervalometer and the re-cycling time would have to be carefully calculated and adjusted to the speed of the aircraft so that correct overlap is accomplished. On the small-scale photographs, the interpreter would distinguish such features as stand type, height, canopy density and acreage of the various stands. On the large-scale sample photographs more detailed measurements can be taken, and more valid appraisal of stand conditions can be assessed. Considerable work has been

done lately on species identification from large-scale photographs (Sayn-Wittgenstein 1961); using the keys that are currently published, the proportion of various species in a stand can be determined. From this appraisal, of course, will come a more accurate determination of stand volume whether it be gross volume or an estimate of net volume derived from the interpretation of stand condition.

Up to this point, this paper has considered some techniques and offered some criticisms of developments which have taken place recently, or which are easily understood as having immediate application. What of the future? How will photo interpretation keep pace with technological advances which will appear? In the following discussion, it will be assumed that the photo interpreter has available to him all the items mentioned.

The use of digital computers will become common-place to obtain volumes of standing timber from height measurements and other data which can be coded and fed directly into the computer. The photo interpreter will still have to "interpret" the photographs, but the task of obtaining volume estimates will be greatly reduced.

As far as photo interpretation aids are concerned, better means of measuring heights, canopy density and crown-widths of trees will be developed. Volume tables for all the major forest types in the country will be available; at present some areas are sadly lacking in this respect.

Improvements in photo interpretation will come with the development of better photographs. In the future, equipment will be available that will automatically print the photographs in the aircraft as well as automatic dodging to ensure proper density over the whole of the photograph. In order to secure better photographs, the ideas must come from the persons who will be using them. It is up to the photo users to initiate the demands; this is one area which is not automatic.

The discussion has centered on the field of forestry since it is this field with which the author is most familiar. The same principles will apply to other areas as well, whether it be geology, wildlife conservation, city planning, highway engineering or gas pipeline location. Military photo interpretation has been purposely left out of the list because it is in a separate category. Too often, the military interpreter has no control over the type of aerial photographs available to him, and he must use the best available photography. In this instance, he is in a class with the interpreter of photographs or imagery taken from a space craft.

The human factor in photo interpretation has not been forgotten. It is unlikely that the human eyes will improve drastically in the next few decades. With proper training, the eyes can detect smaller differences in angle or perceive smaller objects on a photograph but the improvement is limited. Photo interpretation is the same no matter what the quality of the image. The steps in photo interpretation are *detection*, *evaluation* and *decision*. In order to evaluate and decide, the eyes must be able to see something within the limits of accuracy required. Photo interpretation in the future must therefore depend, not so much on the human eye but on improvement in quality and resolution of the photographs presented to the eye. It is in this area that the development must come. Human beings are resourceful and can adjust to changing conditions. If they were not, the first photographs or imagery from space craft would have been discarded long ago as being worthless. The photo interpreter of the future, because he is practicing an art which is not a pure science, will always be able to render appropriate decisions regardless of the type of imagery.

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