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Automated Image Processing in Forestry*

If preliminary results are confirmed, a solid basis for the automated extraction of timber stand profiles will have been established.

Abstract: *A summary of some of the important efforts currently being made in the application of automated image processing in natural resources.*

Efforts to develop automated methods of mapping forest resources from aerial photographs are divided into an interpretation and a mapping phase. Maps are an essential tool for the forest manager providing detailed data of the resource which he cannot retain in his memory for extended periods of time.

This can be viewed as a chain of transitions in which the manager interacts with the resource through the use of remote sensors and mapping instruments from which models are generated, merged, simplified, and reduced to a decision regarding a certain aspect of the resource. The decision is accomplished by using a reverse of the mapping process. A feedback mechanism must operate to maintain a rigorous connection between physical reality and the manager's abstraction of this reality in his decision framework as both procedures are subject to error.

In the broadest sense the important factors in mapping are quality, speed, and capacity. If automated mapping is a justifiable proposition, then for these factors the process will have to be superior in comparison with the equivalent human process.

Automation can replace only a small part of the chain of processes of ever-increasing complexity that leads to the final decision. Complete automation may never come about but it is likely to invade the process at levels which will approach the final decision stage which should be complementary, not competitive.

Capacity and speed are two factors which can be improved most through automation. Automation may directly improve the quality of the mapped data. These possibilities exist for the lower-level, routine decision processes, where machines are faster and capable of handling and storing vast amounts of data.

There is a point beyond which the resource model does not show spatial relationships analogous to those of the actual physical resource in the mapping process, but instead the model becomes an abstraction which is more suited to the decision process. Through the introduction of the digital computer, automation can occupy a decisive role in the determination of this position. Parameters may be obtained through sampling the resource. If a model of the resource is present, the same parameters can be obtained by sampling the model rather than the resource itself, thus, the model has a sophistication proportional to its usefulness in reducing the sampling. One can sample from single aerial photographs, maps, and three-dimensional computer-stored models.

Short of abstraction the most sophisticated model would be one in which all resource components can be related directly to their spatial position in the resource, including all qualitative, and quantitative characteristics relating to any sort of decision that could pos-

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sibly be made. Future problems in decision-making cannot be anticipated, because such a state can never be reached. There exists a trade-off point, at which it becomes advantageous to store resource information to offset an increased data-gathering effort necessary for each individual decision. This point (although precisely determined) may, with increasing related technology, be more extensively interpreted in models which can be made available to the resource manager.

Present computer technology has prompted the development of data banks in which information on the resource components will be stored and retrieved according to its spatial association. To this end, one should distinguish two different categories in this effort: the interpretation phase, and the phase in which the interpreted components are related to their original spatial position in the resource base. The latter phase can be considered mapping in the more conventional sense, though it includes the potential methods to determine the size and shape of components, such as trees.

Information obtained through automatically interpreting digitized aerial photographs cannot be used unless it can be related to the position of the corresponding resource unit. A mapping system is needed to relate all information obtained from aerial photographs to a common three-dimensional reference system.

BECAUSE OF the enormous amount of information handled by an automated interpretation system, the mapping system must be automatic. An automatic digital mapping system is preferable because, in such a system, the scan data used in interpretation can be used to develop a three-dimensional model, and any point on the related aerial photographs can be referenced to this model.

This would be the primary reason for the development of an automated mapping system, but there are other reasons. Accurate terrain models may provide information such as elevation, aspect, and slope for the interpretation process. And a precise representation of the ground surface is the finest requirement for the automated extraction of timber stand profiles.

Black-and-white photographs simultaneously obtained in more than one spectral band can be efficiently acquired and interpreted. The success of this technique depends on the selection of the wavelength bands that will be optimum for discriminating terrain features and conditions of interest, and the employment of aids to photointerpretation such as additive color image enhancement.

Black-and-white multiband photos can be color combined to form nearly any color image desired. The interpreter can be confident that any color composite selected for study can be reliably reproduced using the same multiband photo inputs. Herein lies the real advantage to using the multiband technique as compared to any other photographic method—the system incorporates flexibility in terms of results obtainable and reliability in terms of replicating results.

The tone with which an object is registered on photographic film depends on the amount of light that the object reflects within the spectral zone employed. As the multispectral tone signature of a forest type often indicates the identity or composition of that type, these signatures assume considerable importance for the interpretation of natural resource features on multiband photography. Reliable spectral responses of the terrain features to be identified can be obtained and these data can be used to determine optimum film-filter combinations for multiband photography, define object spectral reflectance characteristics, and predict tone signatures.

In many instances, particularly if forest resources are being analyzed, color infrared film contains more information than standard color film—due to the vast amount of information available in the near–infrared band of the spectrum. Useful information relating to the different reflectance characteristics of terrain features can often be obtained by sensing in more than one specific region of the spectrum; however, neither conventional color nor color-infrared film is always sensitive to those particular wavelengths where the maximum amount of information might be found. Among the methods being exploited for the purpose of alleviating this problem is additive-color image enhancement, a highly flexible technique employing color presentations of carefully selected multiband photographs.

TO MAKE additive color image enhancements, black-and-white multiband photos of an area are simultaneously obtained in each of several spectral bands. By means of a multiple projector system, the multiband photos are optically combined in common register onto a translucent or reflecting screen using a positive transparency of each of these photos. Inserting a different colored filter into the optical path of each projected image, a single false-color composite image is created. Interpretation can be made on a single color composite from which any set of bands within the visible and near-infrared portions of the spectrum can be selected. Color presentation can be altered by changing projector filters to enhance particular relationships and in this way several hundred shades of gray, which is differentiatiable by the human eye on black-and-white multiband photos, can be expanded to several million detectable colors, differing in hue, brightness or saturation. If color film can provide enough information to fulfill user requirements, then certainly one should not bother with black-and-white multiband photography. This is not always true, depending on the information desired, interpretation results can often be greatly improved using reconstituted multiband photography instead of a standard film.

The maximum number of bands that can be employed in black-and-white multiband photography is limited only by the physical construction of a suitable camera system. Optimum focus for each bandpass is achieved by matching the lens with the wavelengths of light for which they are to be used.

Black-and-white multiband photos can be combined into a single color composite with additional flexibility afforded if images are combined because color saturation levels can be altered for a particular bandpass.

Certain environmental variables such as solar illumination, atmospheric scattering and radiation absorption patterns, which influence image tone, are not readily measurable and are difficult to standardize.

To facilitate registration of enhanced multiband photos, all images should have identical spatial positioning with respect to their principal points and each lens should be matched for the band width for which it is being used.

Tone and texture can be numerically recorded by photographic density, this possibility presents a prospective technical basis for an instrumental interpretation of the aerial photograph.

PHOTOGRAPHIC TONE on a black-white or color aerial photograph is the brightness of a lighted and developed area of a photographic layer. The density value is expressed as the percentage of light that is absorbed by the affected area on the prints.

Photographic tone depends on characteristics of the object, such as original remission value, structure and form as well as on the distribution of light on the photographic plane. Atmospheric conditions at the moment of photography, film-filter combination and time of photography, cause an increase in the scattering of gray tone value or the color density of an object. It must be pointed out here that photographic tone on color aerial photos with its three components of color density offers a better possibility than the gray density on black-white aerial photographs for the identification of image forms.

Photographic texture can be regarded as an extension of photographic tone, which not only takes mean photographic tone of an object complex into consideration, but also its variations within this unit. In small-scale aerial photos, form and especially details of single objects cannot be reproduced due to falling below the resolution boundary, texture has significance in identification of the objects. Form, size, spatial distribution and density of these components and their contrast to one another determine the appearance of texture on the aerial photo. Photographic texture, being influenced by the surface structure and the remission value of an object complex, is influenced by film-filter combination, photo scale, illumination, time of photography, atmospheric conditions and the ability to convey the contrast of the photographic system, which have nothing to do with the original character of the object as was the case with photographic tone. It is difficult to set up a comprehensive clear-cut scale for texture similar to that of photographic tone. The instrumental recording of photographic texture will accordingly be more difficult, but not impracticable. Variations in the smallest area of photographic tone, i.e., texture, permits scanning by a measuring instrument along a line. The basis for automation are measurements recorded numerically with its statistic size, as the arithmetic mean, i.e., the average spatial frequency and the mean amplitude of the gray density variation. Photographic texture offers a possibility for the identification of image forms over photographic tone in that change in photographic tone in the smallest area is opened into two additional dimensions: one in a spatial field, i.e., frequency, and one in the tone field, i.e., amplitude (contrast).

Quantitative evaluation of the aerial photo, by means of the measurement of photographic density for identification of land use classes, offers a possibility for the automation of interpretation.

Automatic photo interpretation, which has an analytical description of the forest as the objective has scanning and digitizing of aerial photographs by gray scale density, rectification of the digital image from tilt displacement, from radial displacement and analytical interpretation of the digital image map.

Each object is placed in an orthogonal system with coordinates (X, Y, Z) and height, size and form, and additional terrain description are given.

Either photographic tone or one of the three texture components can be used. As photographic texture can be numerically expressed together with three parameters, the possibility exists of combining the three parameters—mean density, mean amplitude and mean frequency of micrometric densograms—for the identification of forest stand types on black-white aerial photos, so that the best possible differentiation of the objects can be achieved.

SUMMARY

Efforts to develop automated methods for mapping forest resources are being made in which the interpretation phase and the mapping phase can be recognized. Aerial photographs are scanned and digitized, and the digitized data are used directly in the interpretation. A high success rate will be necessary to yield an economically desirable method.

In the context of a wildland resource information system, work on an automated digital mapping system is underway to form an integral part of a resource information system in combination with automated interpretation methods. If preliminary results are confirmed, a solid basis for the automated extraction of timber stand profiles will have been established. With regard to the other objectives of an automated mapping system, improvements are needed mostly to make the system economically feasible.

Often the same information that can be extracted from multiband photography can be obtained as quickly and efficiently by employing color or color-infrared films. Multiband photography requires expensive and complex equipment; this technique should not necessarily be considered a replacement for, but a supplement to, conventional photographic methods. The advantages and limitations of a multiband system versus an existing system must be carefully weighed—and cost effectiveness considered. If the concept of multiband photography is correctly applied, flexibility in terms of image formation and interpretation is offered which cannot easily be matched by any conventional photographic technique.

Obituary

David V. Smith

DAVID V. SMITH, 52, Professor of Forest Engineering, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas, and author of the foregoing article, died unexpectedly on July 5, 1974.

Smith, a native of Georgia, received his Bachelor of Science in Forestry in 1947 from the University of Georgia, his Master of Forestry in 1950 from Duke University and his Ph.D., in Photogrammetry, in 1968 from the State University of New York, College of Forestry at Syracuse. He had been at Stephen F. Austin State University four years, after having taught for 18 years at the Virginia Polytechnic Institute and State University. He was a registered forester in Georgia and a registered land surveyor in South Carolina.

Active in the Society of American Foresters and the American Society of Photogrammetry, Smith has served elected and appointed positions in both societies. At the time of his death he was organizing chairman of the new Agriculture and Plant Sciences Committee of the Remote Sensing and Interpretation Division of ASP, and last year was chairman of the Agriculture and Forestry Committee within the Division. He was involved in two federal research contracts at the time of his death: one from the Johnson Space Center in land use mapping from high altitude photography and one from the U. S. Forest Service in woodland mapping from ERTS-1 and Skylab Imagery.

He is survived by his wife, two daughters and two grandchildren.