INFORMATION THEORY AND ELECTRONIC PHOTOGRAMMETRY*

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ABSTRACT

Information theory is a relatively new branch of science that combines elements of mathematics, physics, and psychology. The theory treats the acquisition, storage, transmission and interpretation of information in its broadest sense. Information theory applies to photogrammetry, mapping, and surveying because the entire process of photogrammetry and map compilation is a flow of information which begins when the aerial camera shutter opens, and ends when the map user reads the finished map. Information theory is a guide and aid in studying, evaluating, and developing old and new methods and instruments for photogrammetry, mapping, and surveying, including methods and instruments for the electronic automation of map compilation.

It appears possible to compile maps automatically by modern electronic methods. Starting with unrectified aerial negatives, electronic equipment can conceivably rectify, scale, orient, print a photomosaic, measure relief, and carve a relief model, all automatically. However, the aerial camera and negative do not acquire and store the terrain information in the form most suitable for electronic map compilation. Methods and systems of "electronic photogrammetry," using no photography, are therefore studied. In particular, the *PRA TSS* is a system devised to scan the ground photoelectrically from the aircraft, record the terrain information as electrical signals on magnetic tape, and then automatically print a photomosaic, carve a relief model, and produce a map to any desired projection. As a by product of this study of electronic photogrammetry, the *PRA* Spiral Scan Method has been devised for automatically recognizing simple, regular, geometric shapes of high contrast, determining their locations and orientations, and measuring their sizes.

INTRODUCTION

THE major technical advances in photogrammetry and mapping have come heretofore from the classical sciences of physics and chemistry; for example from optics, mechanics, and photo-chemistry. Future technical advances and improvements will continue to come from these classical sciences, but with less ease than in the past. For example, as aerial camera lenses become better, it becomes increasingly difficult to design and produce them with wider angle coverage and less distortion; as film bases and emulsions are improved, further improvements in dimensional stability, speed, and resolution become more difficult.

Where in science and technology can photogrammetry and mapping find additional aid for future development and advancement? Some of the answers to this question lie in the field of information theory and in the field of electronics. This paper gives a brief introduction to information theory, and outlines some of the applications of electronics to future developments in photogrammetry, mapping and surveying, as seen by a physicist.

This is the first in a series of papers describing some of the research and development work of the consulting firm of Paul Rosenberg Associates in photogrammetry and mapping. In the limited space of this introductory paper, descriptions of systems and methods are necessarily brief. Fuller descriptions of

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this work will be given in subsequent papers now being prepared by members of the staff of *P.R.A.* for publication in this and other technical journals.

Information Theory

In the history of science there are many instances of the confluence of two or more branches of science into a new discipline. Information theory is one such new discipline that has emerged during the last five or ten years, synthesized from elements of mathematics, physics and psychology. (The term "information theory" will be used in this paper to include "system theory" also.) Shannon,[1] Wiener,[2] and others[3,4] have laid the foundations of information theory and its applications. The theory deals with information in its broadest sense; this includes information in the form of speech, written or printed words, drawings, photographs, pantomime, semaphore signals, electric telegraphy, telephone messages, or radio signals. Information theory treats the acquisition, storage, classification, transmission, and interpretation of information. An example of the acquisition of information is a person reading a book, listening to a spoken sentence, or looking at a picture; examples of the storage of information are printed books, drawings, photographs, phonograph records, magnetic recording tapes, and punched cards for calculating machines; examples of transmission of information are telegraphy, radio, visible light waves, and sound. Information theory endeavors to find the common factors in all these information processes and instruments, to study their efficiency, and to evaluate them.

One of the most practical and successful applications of information theory to date has been in electrical and radio communications engineering, where information theory is frequently called communications theory; as such it studies the channel capacity, bandwidth, and noise of telegraph, telephone, radio, and television systems. For example, the problem of how many separate messages can be transmitted simultaneously over a single wire without interference is a problem in information theory; similarly, information theory helps answer the question of how many television channels can be compressed into a given band of frequencies if the television images are required to maintain certain specifications of image quality, resolution, and dynamic range of gray scale and color.

In common usage, we speak of the amount of information in a message or in a picture, but this is largely a qualitative concept. Information theory is characterized by its quantitative concept and treatment of information. In information theory, information is considered to be the removal of uncertainty about a situation or an event. The quantity of information is defined as the amount of uncertainty that is removed, and is inextricably associated with the a priori probability of the fact or event concerned. The unit quantity of information is the "bit," which is an abbreviation for "binary digit." One bit of information is the removal of uncertainty between two equally probable possibilities. For example, if a coin is tossed honestly so that the probability of occurrence of a head is equal to that of a tail, then the information that the coin did fall as a head is one "bit" of information.

[1] Shannon, Claude E. and Weaver, Warren, *The Mathematical Theory of Communication*, The University of Illinois Press, Urbana, Illinois, 1949.

[2] Wiener, Norbert, *Cybernetics*, John Wiley & Sons, New York, 1948.

[3] "Report of Proceedings, Symposium on Information Theory, London, England, Sept. 1950," *Transactions of the Inst. of Radio Engineers Professional Group on Information Theory*, New York Feb. 1953.

[4] Stumpers, F. L., *A Bibliography of Information Theory*, Research Lab. of Electronics, M.I.T., Cambridge, Mass., 2 Feb. 1953.

If there are n possibilities, with n greater than 2, and all the possibilities are equally probable, the statement that one of these possibilities has actually occurred gives us an amount of information measured in bits by the expression $\log_2 n$. For example, consider the simple array of four squares in a checker board pattern as in Figure 1, such that it is equally likely that a checker lies in any one of the four squares. Suppose we are told that a checker lies in the lower left square of this pattern. How many bits of information are conveyed thereby? Since $n=4$, the answer is $\log_2 n=\log_2 4=2$ bits. To determine this in another way, first ask the question: Is the checker in the upper pair of squares or in the lower pair of squares? The answer, namely that the checker is in the lower pair of squares, constitutes one bit of information. We then ask the final question: Is the checker in the left or the right square of the lower pair? The answer, namely that the checker is in the left of the lower pair of squares, is a second bit of information. The total amount of information is therefore two bits.

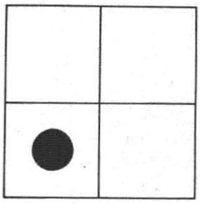

FIG. 1

These same basic definitions of information and the quantity of information apply when the information content of an aerial photograph is considered. However, in this case the a priori probabilities of the points or elements which compose the picture present difficult problems. The relations between the points in the photograph become important. It becomes necessary to make a careful study and analysis of the correlation between the intensities of the points that make up the images on the photograph. This involves a study of the entropy of the ground terrain.

R. E. Williams and M. Kochen of the *P.R.A.* research staff have succeeded in deriving expressions (to be published in subsequent papers) for the a priori entropy of ground terrain, or of a photograph, as an area display of information. These expressions are based upon the assumption that the correlation between intensities decays with increasing separation of the points and with increasing intensity differences between the points. It is anticipated that these entropy expressions will eventually be tied in with experimental data which are being obtained in other laboratories on the correlation of intensities in aerial photographs.

The application of information theory to photogrammetry and mapping becomes apparent when we stop to consider that the entire process of photogrammetry and map compilation is a process of acquiring, storing, interpreting and transmitting information, from the time the shutter clicks in the aerial camera, through a complicated chain of events, to the time the eventual user reads and employs the map. A simplified way of considering this chain of events is block diagrammed in Figure 2 for the case of a map compiled from aerial photography with stereoplotting equipment. The rectangular blocks in the diagram represent stages in the over-all photogrammetric process during which the information is processed or transmitted, or affected in one way or another; in terms of information theory, the rectangular blocks represent filters. The circular blocks in the diagram represent stages in which the information is stored; in terms of information theory, the circular blocks are memory or storage devices. The figure diagrams the flow of information energy beginning with the light reflected from the earth's surface into the aerial camera. The first filter through which the information passes is the aerial camera, the shutter and lenses of which process the information by collecting and focusing light onto the photographic emulsion of the aerial negative. The information is temporarily stored in the undeveloped photographic emulsion, and is again filtered during the de-

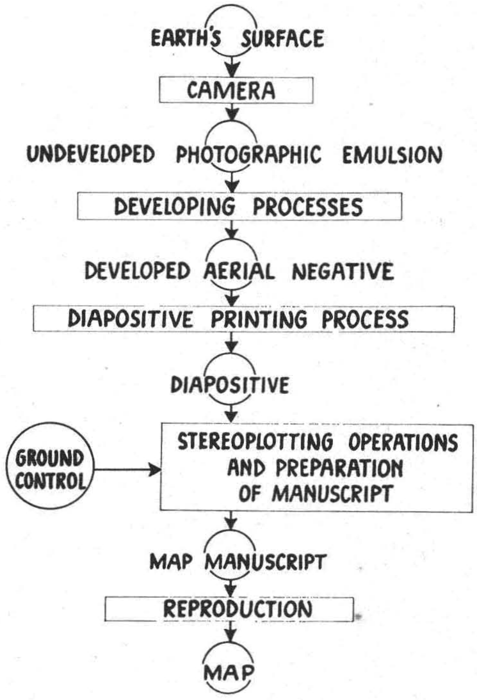

FIG. 2. Block diagram of the flow of information in conventional map compilation with stereoplotting equipment. Circles represent storage. Rectangles represent filters.

veloping process. The information is then stored in the developed aerial negative. Another filter process takes place when the image in the developed aerial negative is transformed into an image on the diapositive. The stereoplotting operations and the preparation of the manuscript are another set of filtering operations, some quite complicated, which are lumped together in one rectangular box in this diagram for simplicity. Additional information enters the information chain at this point in the form of ground control as indicated in the diagram. The information from the diapositive and ground control, filtered by the stereoplotting operations, is stored in the map manuscript. A final filtering operation takes place when the map is reproduced. The final storage is in the finished map.

In each of the filtering operations, represented by the rectangles in Figure 2, some information may be lost or degraded. Some of this loss of information may be deliberate and intentional; for example, in the preparation of the map manuscript much of the information in the aerial negative is discarded as being unimportant to the user of the map. Other loss of information may be due to the inevitable introduction of "noise" as it is called in information theory. (The use of the term noise in information theory originates from its application to communications engineering, where electrical noise or static can cause some information to be lost during the transmission of a message by telephone or by radio, for example.) A certain amount of noise affects the flow of information in every filter in the photogrammetric mapping process. For example, dust or haze in the atmosphere, which may render a picture fuzzy, is an obvious case of noise; the imperfect resolving power of the lens system of the aerial camera may be considered noise; migration of the individual grains in the photographic emulsion is a cause of noise during the developing process; loss of resolution in reducing the aerial negative to a diapositive introduces noise again; a mistake in photo-interpretation or identification is another source of noise. The advantages of applying information theory to photogrammetric processes are that all these sources and forms of noise can be compared with each other, and can be compared quantitatively with the noise introduced by different methods of mapping using different instruments.

Another quantity that information theory can study in the photogrammetric and mapping procedure is the capacity of the various storage centers for storing information. For example, one can ask the obvious question: how does the information storage capacity of the aerial negative compare with the storage capacity of the diapositive, and how in turn do these storage capacities compare with those of the map manuscript and the finished map? Or: what is the minimum scale of the aerial negative that can be tolerated in a given system to store enough information to make a map of a given scale and specification?

As one example of the application of the quantitative definition of information to photogrammetry, we have calculated and compared the storage capacities at the various steps of the conventional map compilation process, using Multiplex compilation on the one hand and Kelsh compilation on the other. The results are: (a) the limited storage capacity of the Multiplex diapositive seriously restricts the amount of information available in the later stages of Multiplex compilation; (b) each storage center in the over-all Kelsh compilation system has adequate capacity, compared to its adjacent storage centers, to permit uniform transfer of information. Although these results in themselves are not startling or new, they are significant because they are derived by using the information theory definition of information, and because they confirm, and are additional evidence for, the recognized advantages of Kelsh over Multiplex compilation. Similar computations and comparisons of information storage capacities can be made for other mapping systems using other methods and other instruments.

Information theory is thus an important tool with which to study, criticize, and evaluate old and new methods and instruments in photogrammetry, surveying, and mapping.

Electronic Photogrammetry

When the methods and instruments of photogrammetry and mapping are studied from the viewpoint of applied physics and information theory, the use of electronic methods for acquiring, storing, transmitting, and filtering the information suggests itself strongly. For example, it is possible to scan an aerial negative photo-electrically in a raster of straight, narrow lines, parallel to each other and very closely spaced, (or in some other geometric scanning pattern which covers all points on the negative), so that the pattern of gray shades that compose the photograph is transformed into a varying electrical potential or into a modulated radio signal. These signals can then be stored on magnetic tape in a manner similar to that used in audio recording. The information which was stored in the form of an area display on the aerial negative is now stored and available as a linear array on the tape; (information in this latter form lends itself to mathematical analysis by the theory of stochastic processes). When the tape is played back, the resulting electrical signals can conceivably be treated so as to accomplish electronically and automatically all the photogrammetric and mapping processes of orientation, rectification, change of scale, control, and measurement of relief.

One such postulated system is shown conceptually in the schematic diagram of Figure 3. The spot of a flying spot scanner is focused optically onto a conventional unrectified aerial negative. The light transmitted through the negative is collected and measured by a photocell, the output of which is amplified. The aerial negative is scanned in a series of closely spaced straight lines, first in the longitudinal direction (approximately the direction of travel of the survey aircraft) and then in the transverse direction (at right angles to the longitudinal direction). An electronic switch routes the amplified photocell output to the appropriate one of two magnetic tapes, (storage A), one of which stores the longitudinal scans and the other the transverse scans. The scans are then oriented, rectified, and scaled by electronic comparison, adjustment, and matching. A change of scale is equivalent electronically to a change in the speed of playback (of one set of scan signals from storage relative to the speed of playback

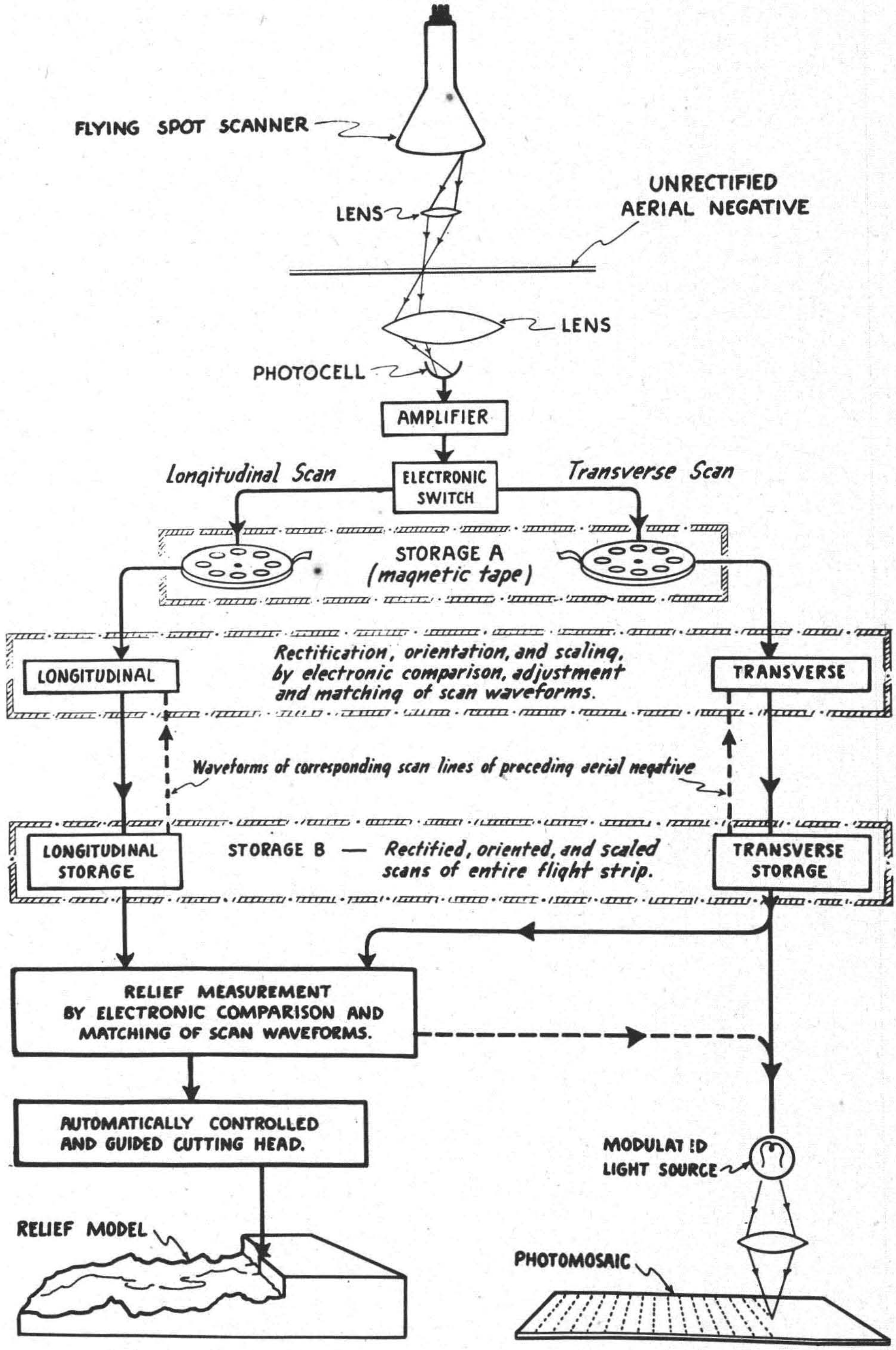

FIG. 3. Schematic diagram for automatic production of photomosaics and relief models.

of another set of scans, or relative to the speed of travel of the modulated light source or other facsimile reproducing head which produces the output negative or photomosaic, or relative to the speed of travel of the cutting head which automatically carves out a relief model. Rectification is performed electronically by differentially expanding and contracting the time base upon which the signals are played back from the tape, as well as by shifting the signals along the time base; (crudely speaking, this is equivalent to making the tape play back faster and slower in different portions of the playback). Relief measurement is carried out electronically by comparing and matching the electrical waveforms produced by scanning corresponding areas on the overlapping aerial negatives of adjacent exposure stations. (Relief measurement by waveform matching is being developed by the Engineer Research & Development Laboratories, U. S. Army, and by Wright Air Development Center.) Relative orientation also is accomplished electronically by matching wave forms obtained from overlapping portions of aerial negatives. The rectified scans are stored in storage *B*, whence they are fed back to be matched with the waveforms of corresponding line scans from overlapping areas of adjacent aerial negatives. Control can be carried out automatically by readjusting indicated coordinates in a least squares fit to known coordinate values.

The final electronic outputs of the foregoing system automatically print a photomosaic and automatically cut a relief model. The photomosaic is printed on photosensitive paper in a series of very closely spaced lines by a facsimile method of high resolution, using a traveling light source modulated by an output from storage *B*, Figure 3. The relief model is cut automatically from a block of machineable material (e.g. plastic) by a traveling cutting or routing tool which is guided and controlled by an output of the electronic relief measurement.

Variations of the foregoing system are obviously possible. For example the longitudinal and transverse scans can be stored on a single tape; or it might be sufficient to scan transversely only, and not longitudinally; or a scanning pattern more suitable to automatic orientation and rectification might be used. However, our study shows that the system presents very difficult engineering problems regardless of these variations. The difficulties stem largely from the fact that conventional aerial photography and the conventional aerial negative acquire and present the terrain information in a form that is not convenient and efficient for subsequent electronic, fully automatic compilation.

Consequently we have been led to devise and study methods for acquiring the basic terrain information without using photography, i.e. using no aerial negative. These methods may be called "*non-photographic photogrammetry*" or "*electronic photogrammetry*." Three such methods, discussed below and diagrammed in Figures 4, 5 and 6, are called respectively the "television method," the "single-line-scan television method," and the "spot-scan photomultiplier method"; although methods similar to these three have been proposed and are being developed by other laboratories for other purposes, *P.R.A.* are believed to be the first to study the application of these methods to map compilation.

The television method is depicted in Figure 4. The survey aircraft carries a television camera instead of a photographic camera. An image of the ground is projected through a lens system upon the face of the *TV* pick-up tube, where the image is electronically scanned. The output of the scans modulates an *FM* transmitter which radios the scan waveforms to a ground station where they are recorded and stored on magnetic tape. Map compilation then proceeds automatically by electronic methods similar to those indicated in Figure 3 beginning with storage *A*.

Study shows that the television method described above is lacking in many respects for map compilation. For example, it does not appear possible to obtain high enough resolving power and at the same time retain enough wide-angle coverage to provide good relief determination from overlapping exposures. Furthermore, a very large bandwidth would be required to transmit the *TV* information rapidly enough. Still another disadvantage is that the method is not sufficiently sensitive to low levels of ground illumination.

The single-line-scan television method is diagrammed in Figure 5. The survey aircraft carries two *TV* pickup tubes, each with its own lens system, one looking forward and one looking aft. Only a single line on each *TV* pickup tube is scanned. The scanned line is perpendicular to the direction of flight. At each instant, the system therefore "looks" at only a narrow line on the ground in the transverse direction forward of the aircraft (scan 1 in Figure 5) and a similar transverse narrow line backward of the aircraft (scan 2). The forward motion

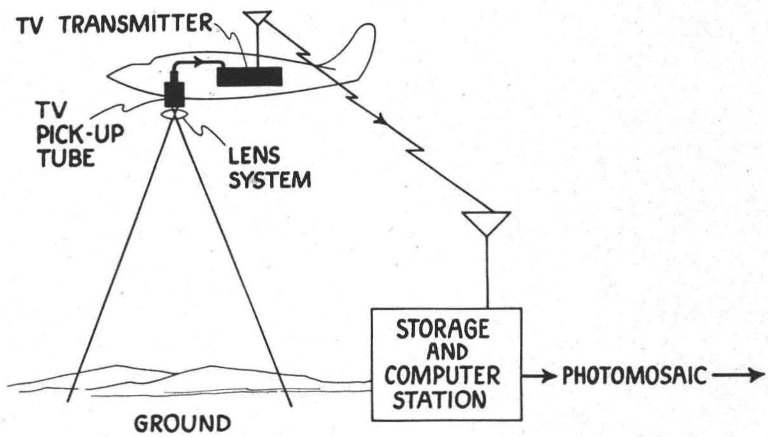

FIG. 4. Television method.

of the aircraft causes these lines to sweep out the area being surveyed. The scan waveforms are transmitted by radio to a storage and computer station on the ground. Relief is determined electronically by comparing and matching portions of the waveforms from the two scans of the same ground line, corresponding to two stereoscopic views of this ground line. The other steps in the map compilation process are accomplished electronically as previously described.

The single-line-scan television method of Figure 5 has the following advantages over the television method of Figure 4: somewhat higher resolution is possible with effectively wider coverage; a good stereo angle can be maintained; the bandwidth for transmission to the ground station need not be as wide.

The spot-scan photomultiplier method is diagrammed in Figure 6. The light from a small spot on the ground is collected upon the photocathode of an airborne photomultiplier tube through a lens and aperture system. Rotating mirrors or prisms move the viewed spot along the ground in a line at right angles to the aircraft's flight direction, thus scanning the terrain. Two such photomultipliers are carried in the aircraft, each with its own set of lenses and rotating mirrors. One photomultiplier looks forward and the other aft, similar to the arrangement of the two *TV* pickup tubes in Figure 5, thereby providing the stereoscopic type of information required for relief measurement. The photomultiplier output signals are transmitted by radio to a ground station where the scan waveforms are stored on tape and used for automatic map compilation in the same way as in the other electronic methods.

The spot-scan photomultiplier method has important advantages over the television method and the single-line-scan television method. The major advantage is the much higher sensitivity to low levels of ground illumination; this advantage accrues from the use of the photomultiplier tube. Indeed, the sensitivity of the spot-scan photomultiplier is likely to be greater than is obtained in conventional aerial photography. Partly as a result of this greater light sensitivity, the spot-scan photomultiplier method has much higher resolution than the television and single-line-scan television methods, and appears capable of a resolving power equal to or possibly greater than that of conventional aerial photography.

The spot-scan photomultiplier method for acquiring terrain information is used and extended in an automatic map compilation system called the *PRA terrain scanning system* (abbreviated as *PRA TSS*, or simply *TSS*) which we have devised and are studying. No aerial camera or photographic film is used in

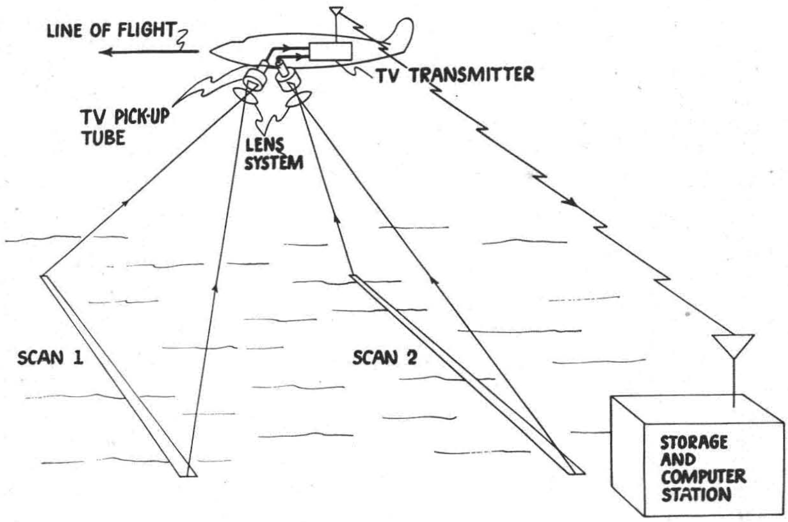

FIG. 5. Single-line-scan television method.

the *TSS*. Instead, the aircraft carries three photomultiplier tubes each with its own aperture, telephoto lens system, and rotating mirrors; one of these tubes with its optical components is diagrammed in Figure 6. Three simultaneous scans are produced, as diagrammed in Figure 7. One is a longitudinal scan (in the direction of the aircraft motion) directly under the aircraft. The second scan is transverse to the aircraft motion and forward of the aircraft at a fixed angle. The third scan is likewise transverse to the aircraft motion, but is directed backward of the aircraft at the same fixed stereo angle as the forward transverse scan. The transverse scans are spaced closely, or overlapped, so that the entire area is covered as the aircraft advances. All three scans extend from horizon to horizon, making it possible to consider using horizon indications to measure aircraft roll and pitch.

The outputs of the photomultipliers are transmitted by *FM* radio to a ground station where the signals that constitute the scan waveforms are continuously recorded and stored on magnetic tape. Alternatively this terrain information can be recorded in the *TSS* aircraft on tape, and delivered as a roll of tape to the ground computer station after the survey flight is completed; (this alternative recording procedure can be used in the television, single-line-scan television, and spot-scan photomultiplier methods also). Although magnetic tape is not as compact a storage medium as photographic film, nevertheless the amount of tape required to store all the information of an aerial survey mission is *not* too bulky or heavy for practical airborne use. Dimensional instability of the tape is fully corrected by recording on the same tape the monitoring signals from a stable, crystal-controlled oscillator during the recording of the ground

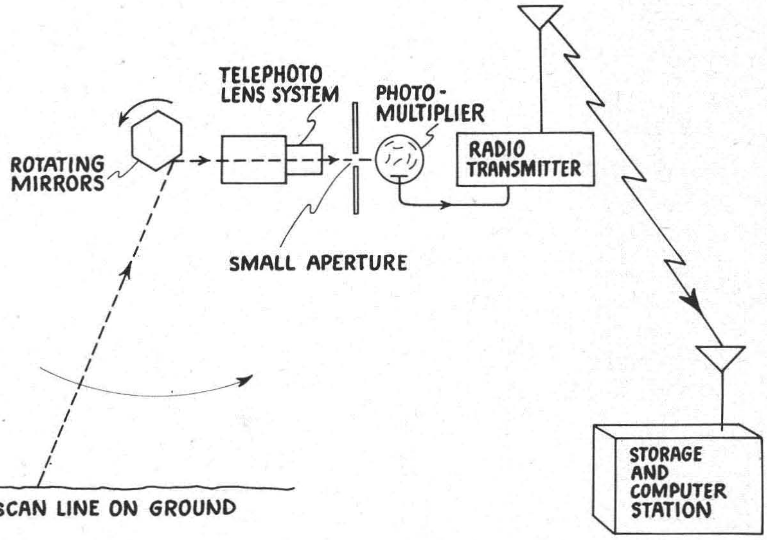

FIG. 6. Spot-scan photomultiplier method for electronic photogrammetry, used by the PRA TSS

scans, and then controlling the speed of playback to reproduce the monitor signals at their original frequency.

At the *TSS* computer station on the ground, the forward motion and position of the aircraft corresponding to each pair of transverse scans is measured automatically by electronically comparing the waveforms from successive longitudinal scans. Pitch is likewise determined by waveform comparison of the longitudinal scans. Roll and lateral drift are measured by comparing and matching the forward and backward transverse scans which covered the same ground line at different times. It is even possible, conceptually, to measure yaw of the aircraft by automatically sampling and comparing portions of successive transverse scans. Using the foregoing data, plus the recorded readings of a radar altimeter, the transverse scans are automatically scaled, corrected for irregularities of aircraft motion, and properly oriented with respect to each other. Relief is measured automatically by electronically comparing the waveforms of portions of the forward and backward transverse scans of the same ground line.

The final electronic outputs of the *PRA TSS* automatically print a photomosaic and cut a relief model in the same way as is described above in the discussion of the final step of Figure 3. In addition, the *PRA TSS* conceptually prints a finished map by supplying stored map symbols semi-automatically at locations identified by a photo interpreter from a cathode ray tube display. Computing equipment automatically transforms the map to any desired map projection.

From the brief discussion of electronic photogrammetry in this paper, including the *TSS* just described and the *spiral scan method* described in the next section, it should not be inferred that the required electronic methods and instruments are simple to develop. The engineering problems in electronic photogrammetry are very considerable. No one appreciates the complexity involved better than do the author and his colleagues, who have been studying these problems and attempting the preliminary engineering development. It will be a long time before completely automatic, electronic photogrammetry is actually at hand. Nevertheless, the difficulties that stand in the way are engineering

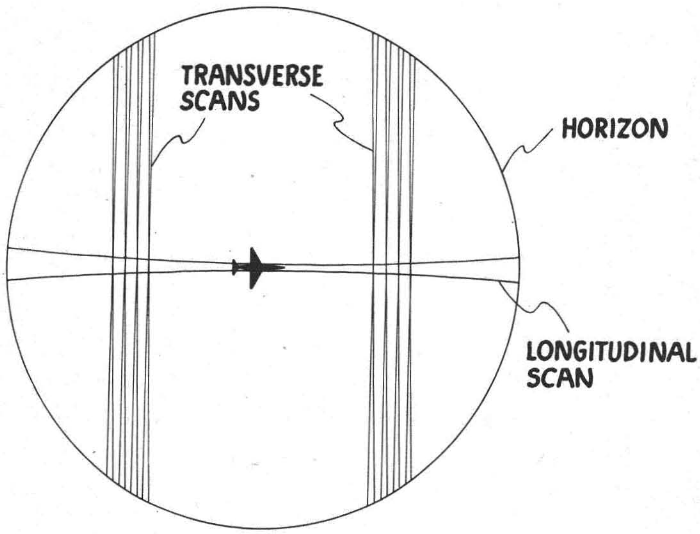

FIG. 7. Pattern of ground scans in the PRA TSS.

difficulties only; there is nothing in these methods and systems that is basically impossible as far as the physics and the mathematics of the problem are concerned. Consequently we can look forward with confidence to the partial automation of photogrammetry and map compilation in the not too distant future. In particular we can expect to see early success in the development of electronic, automatic relief measurement.

SPIRAL SCAN METHOD FOR AUTOMATIC RECOGNITION

The photo interpreter will inevitably play an important role in all the "automatic" methods and systems of electronic photogrammetry discussed above, including the *PRA TSS*. Nevertheless, the author and his colleagues have been bold enough to give some thought to the possibility of automatic or semiautomic recognition in map compilation. The information theory approach to this fascinating problem leads to intriguing psychological considerations of "gestalt," or the perception of form. This is a relatively little understood branch of applied psychology to which information theory may contribute significantly.

As a by-product of this study of the problem of automatic recognition, we have devised a method, called the *PRA spiral scan method*, for the automatic recognition of regular geometric shapes and figures. This method is theoretically capable of automatically recognizing circles, triangles, squares, pentagons, hexagons, trapezoids, and similar shapes having certain symmetry, when they appear in high contrast as black silhouettes against a white background (or white silhouettes against a black background). At the same time that the method recognizes these shapes, it also automatically pinpoints their locations, measures their sizes, and determines their orientations.

In the *PRA* spiral scan method, a flying spot scanner scans the transparent negative (or opaque print) on which the shapes are to be recognized. The light transmitted through the negative (or reflected in the case of an opaque print) is collected by a photocell. The scanning pattern is a spiral, the center of which moves as a whole across the negative in a raster of closely spaced straight lines. The speed with which the spiral is described is large compared to the speed of travel of center of the spiral. The photocell output changes abruptly whenever the spiral scan crosses the border of a shape, i.e. whenever the scanning spot enters or leaves the silhouette.

When the center of the spiral scan is at the center of the shape to be recognized, the photocell gives an output signal characteristic of that shape. Figure 8

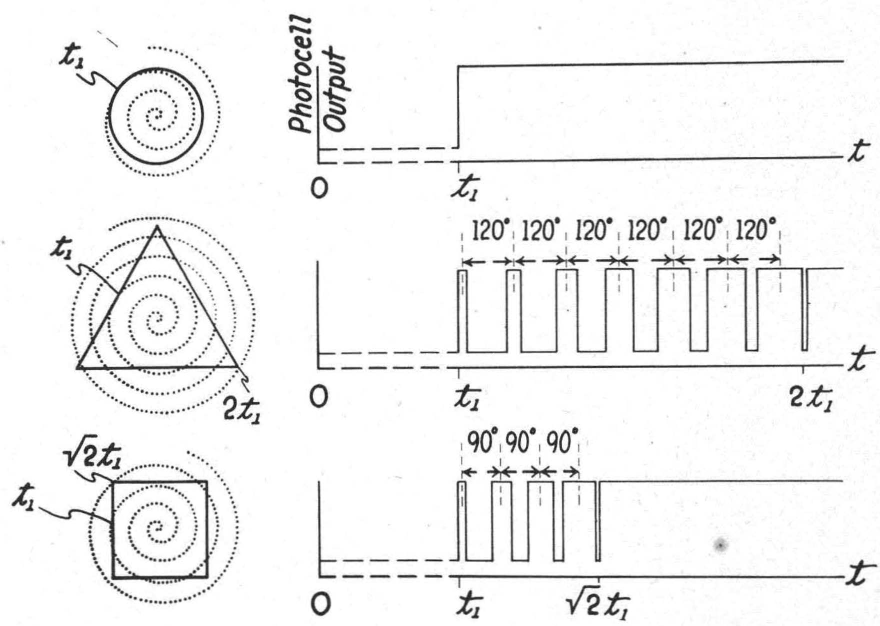

FIG. 8. PRA Spiral Scan Method for automatic recognition.

shows the characteristic output waveforms for a circle, an equilateral triangle, and a square. Discriminating circuits electronically recognize the differences between these signals. Each regular geometric shape produces a characteristic frequency as well as a characteristic wave form. For example, the centers (approximately) of the pedestal pulses for the equilateral triangle are 120 degrees apart, whereas the corresponding spacing for the square is 90 degrees. It is thus possible to identify the geometric shapes automatically by their characteristic frequencies as well as by their waveforms.

The location of the center of the shape is given automatically by the location of the center of the spiral scan when the characteristic waveform is detected. The size of the identified shape is measured automatically by the time, t_1 at which the centered spiral first intersects the border of the shape. (For clarity of illustration, the sizes of the triangle and square in Figure 8 are chosen to circumscribe the circle. As a result, the value of t_1 for the circle, triangle and square so chosen are the same.) The orientation of the shape is given automatically by the angles at which the centered spiral intersects the borders of the shape.

Recognition of these simple geometric shapes of high contrast by the *PRA* spiral scan method is a far cry indeed from useful automatic recognition or interpretation. Nevertheless, the method is of interest because it is at least a first step, albeit rudimentary, toward the possible automation of recognition. The problem of fully automatic recognition or of useful semi-automatic recognition will have to deal with many difficult problems of gestalt, including problems of shade, texture, and correlation.

ACKNOWLEDGMENTS

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NEWS NOTES

ABRAMS INSTRUMENT CORPORATION EXPANDS FACILITIES

Abrams Instrument Corporation, pioneer designers and manufacturers of precision aerial photographic surveying and interpretation equipment, timing and control mechanisms have added a Research and Test Center.

Housed separately in a recently acquired location at 114 North Larch Street, the Research and Test Center has been furnished with completely modern equipment. All types of design, stress, fatigue, endurance and environmental testing can be accomplished. These tests are completed in controlled chambers accurately simulating altitude and various environmental conditions as necessitated by latest developments and new horizons of the jet aviation age.

Another installation at Abrams new Test Center is the large modern radio noise screen room. Completely equipped with latest test devices, radio noise testing can be accomplished on all types of equipment through all frequencies required by military contracts.

Current plans include the offering of product analysis and testing services to outside manufacturers as well as the testing of all production items of the Abrams Instrument Corporation.

KODAK REVISES DATA BOOK ON AERIAL PHOTOGRAPHY

A new and extensively revised fourth edition of the Data Book "Kodak Materials for Aerial Photography" has just been published by the Eastman Kodak Company. Generally acknowledged as one of the standard reference works for all aerial photographers, the book has now been revised in detail to bring all sections up to date and to provide the latest data for professional aerial picture taking.

Of particular interest to readers will be data on the new, high-speed Kodak Infrared Aerographic Film recently made available by Kodak for maximum penetration of haze and for other special purposes. This emulsion, which is twice as fast as the previous Kodak Infrared Aerographic Film, is described in detail with sensitometric data and suggestions on processing.

Copies of Kodak Materials for Aerial Photography will be priced at 50 cents each and will be available through Kodak dealers.