glean its full meaning and to better understand the event that has passed.

Such is the scope and significance of photogrammetry, which, of course, includes its sometimes headstrong offspring, photo interpretation.

What are its parts?

I. Photography. II. Interpretation. These can be broadly subdivided as follows:

Photography: *Image formation*
Image recording

Image formation: *Geometrical and Physical Optics*
Light sources and Photometry

Image recording: *Light sensitive materials*
Photographic sensitometry
Resolution and control of contrast

Interpretation: *Quantitative* "This point has these coords . . . plus or minus . . ."
Qualitative "This is muskeg
or a shock wave
or a chromosome"

Quantitative: Perspective—scale—displacements and distortions
Stereoscopy
Restitution

2D or 3D by graphical
optical-mechanical
analytical

Qualitative: The systematic accumulation of knowledge regarding the appearance of reality in varying circumstances.

In which connection I am reminded—being a Scot—of those lines by Burns:

"Oh wad some power the Giftie gie us
To see oursels as others see us
It wad frae many a blunder free us
An' foolish notion."

How often this, in a slightly different form, must have been the prayer of the photo interpreter.

To see as others see
It wad frae many a blunder free us
An' foolish notion.

This is the subject—its significance, its scope and its content—as I see it. Others are going to discuss its place in education.

PHOTOGRAMMETRY IN THE CIVIL ENGINEERING CURRICULUM*

Professor Francis H. Moffitt, University of California, Berkeley, Calif.

TO LAY down the needs of the civil engineer in the way of photogrammetry is to observe current practice in the profession, to recognize the lack of understanding of photogrammetry, and to note the gross omission of this science in areas where it specifically applies. Any person who reads PHOTOGRAMMETRIC

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ENGINEERING regularly cannot help but realize where photogrammetry is used and to what extent it is used. As a matter of fact, the photogrammetric exploits of engineers and photogrammetrists are written in popular magazines and in the daily newspapers, but perhaps not the way we like to see them written. The reporter for one of the California newspapers, for example, defined terrestrial photogrammetry as the process of taking pictures from an airplane.

The following actual happenings illustrate a lack of understanding of photogrammetry in civil engineering: Two engineers came into the office one day with a packet of ten-year-old AAA 7 by 9 inch contact prints taken at a scale of about 1:20,000. The photographs covered a series of rapids in a river of this country. They asked if we could plot half-foot contours of the surface of the rapids from these photographs.

Another example is a team of engineers who desire to set up a mapping section and plan to use a pair of Federal enlargers as their plotting instrument.

Photogrammetry as a device for gathering experimental data or for carrying out research in civil engineering is not being exploited to the fullest degree. Aerial photographs themselves are not being used in engineering reports as frequently as they should be.

Photogrammetry is applied to civil engineering in the following general areas: Interpretation of aerial photographs, topographic mapping, planimetric mapping, presentation of reports, experimental measurements and inventorying. The construction and sanitary engineers are perhaps the least frequent users. The hydraulic engineer uses all areas, as does the irrigation engineer. Insofar as foundations are concerned, the structural engineer would resort to the interpretation of aerial photographs. Certainly, the general civil engineer who does not specialize would make demands on all areas of photogrammetry.

I believe that a course in photogrammetry which is designed for all civil engineering students, regardless of option, should include as many of the areas just mentioned as is structurally possible. I believe that photo interpretation should not be taught in such a course. Photo interpretation itself presumes specialization and a certain background in and familiarity with other sciences, especially the earth sciences. It should be a course separate in itself for select engineering students who have common or nearly common background in the things being interpreted, or else it should be included in a course for these students.

Topographic and planimetric mapping, experimental measurements and certain types of inventorying depend on the metrical characteristics and geometry of photo systems. All areas depend on sources of supply, methods of procurement and availability of photographs, negatives, diapositives, calibration data and the like.

Assuming that a basic photogrammetry course is to be designed for all civil engineering students, I believe it should be elementary in nature and should consist of the following topics in their order of presentation.

OPTICS

This is not new to a civil engineering student since he is presumed to have had physics in his lower division. Significance of focal length, principal distance, conjugate distances, nodal points, radial distortion and resolution in a simple lens system should be discussed.

AERIAL CAMERA

The student must be impressed at the very beginning with the importance of interior orientation of a cartographic camera. After all, the result of a single exposure by a calibrated camera is identical to reams of field notes of horizontal and vertical circle readings of a transit, taken at one station. The interpretation of the calibration data which includes the equivalent focal length, the calibrated focal length and its associated distortion curves along the diagonals, the photographic coordinates of the principal point and the dimensions of the focal plane opening must be explained and demonstrated.

NOMENCLATURE

A glossary of terms which will be used in discussing elementary photogrammetry must be established. This need not be extensive since new terms will be handled later on in the course of presentation. In the discussion of the terms, the student is introduced to

GEOMETRY OF A PHOTOGRAPH

The scale of a photograph as it is affected by change in altitude, in focal length, in terrain elevation, is a critical phase of photogrammetry. We admit that the concept of scale is not complicated, but consider the various ramifications that this simple concept can lead to. Scale affects ground coverage, overlap and side lap in very rugged areas. Long focal lengths used for mosaics affect scale. Short focal length photographs while increasing base-height ratios for given overlaps affect scale. The limitations of stereo-plotting instruments affect flying height and consequently the scale of photography. All these must be amplified at the appropriate time when the proper subject matter is under discussion. Relief displacement, the effect of tilt on images, the determination of distances and areas, are all a part of the geometry of a photograph.

CONTROL

A discussion of control should cover the function of the U. S. Coast and Geodetic Survey in establishing the main framework, the state plane coordinate systems and the advantages in using them, supplemental control, photo control, current practice in the use of the altimeter techniques, trig traversing, subtense traversing, conditioned resection, trig leveling and elevation meters. The application of Shoran, radar and the geodometer, to photogrammetric control can be discussed although not in too much detail. The placement of horizontal and vertical picture point control had better be left to the various photogrammetric processes in turn.

PLANIMETRIC MAPPING

Establishing auxiliary horizontal control by radial line principles, the use of the tracing table, overhead projector, vertical sketchmaster, radial plotter and other devices should be dwelled on. The transfer of planimetric detail, however, is not as important as the radial line principle which is fundamental in itself.

MOSAICS

The materials used and the techniques in laying down prints should be demonstrated. A distinction should be made between uncontrolled and controlled mosaics, and the procedure for controlling a mosaic should be outlined. A student must be forced to realize the conditions under which a controlled mosaic approaches the accuracy of a planimetric map, and the conditions where he may not consider the substitution of one for the other.

OBLIQUE PHOTOGRAPHS

The elements of exterior orientation and how they are computed are basic to a consideration of obliques. A student should have an appreciation of a graphical rectification of obliques by means of the perspective grid to produce planimetric maps. The use of oblique photographs in illustrations, and the superposition of proposed engineering works onto obliques by means of the perspective grid should be discussed.

TOPOGRAPHIC MAPPING

I believe that this phase of a basic photogrammetry course is best handled by first discussing the design and operating principles of a projection type instrument such as the Kelsh and the Multiplex. This should be followed by a complete treatment of all stages of planning ground control, aerial photography, compilation, checking and finishing of a topographic map, assuming that a fictitious area is to be mapped and the instrument previously discussed utilized. The fictitious map should be of fairly large scale with a small contour interval, not only to give it the engineering significance but to present more forcefully the limitations of the instrument in selecting scale insofar as flying height and range of relief is concerned, and to point up the necessity for the economical placement of ground control. During this phase of instruction, the student should begin to develop a feeling for the writing of specifications. He should also begin to understand that photogrammetry has its compromises. For example, if the specifications for this fictitious project call for a manuscript map at one scale, aerial photographs at another scale and a controlled mosaic at still another scale, the student should realize that with a short focal length to give a favorable base-height ratio for stereo compilation, the resulting photographs may not be very desirable for the construction of mosaics.

TERRESTRIAL PHOTOGRAMMETRY

Numerous applications of the principles of photogrammetry to problems other than those in the mapping field are to be found in the literature. It would be most unfortunate if these areas are not explored for the benefit of the students. Determining space positions of experimental models in engineering research by stereo motion picture photography seems to me to be most appropriate. An example of an application of this type of photogrammetry is in mapping the surface of a hydraulic jump, or in precise determination of wave shapes. Another example is in the determination of instantaneous space positions of various portions of vehicles in negotiating turns, bumps and the like.

One project I have in mind which is being carried out at present has need of this type of photogrammetry. In research on prosthetic devices, particularly on artificial limbs, the researcher must know the instantaneous orientation of various parts of the body while a man walks, turns and ascends or descends stair steps. Stereo photogrammetry with suitable motion picture photography, careful attention to details in the object space and to camera and base arrangement, proper enlargement of the film and orientation in the plotting machine will give the answers.

I firmly believe that if civil engineering students are versed in the fundamentals of interior and exterior orientation of cameras and plotters, of photo base, desirable parallactic angle, working depth of plotters and of proper calibration of equipment, then the students in turn can suggest other areas of application of this technique.

Most of the details of subject matter appropriate to a course such as I have outlined above can be found in several excellent articles appearing in PHOTOGRAMMETRIC ENGINEERING over the past five years, and in the chapter on education in the new volume of the MANUAL OF PHOTOGRAMMETRY. Detailed listings of basic laboratory equipment and of desirable equipment are also given in these articles.

Civil engineering students graduating from colleges and universities in these times are expected to know a little about everything in the broad field. Some colleges tend to favor a general civil engineering curriculum. Other colleges offer options or lines of specialization tending to give a student a little bit of a lot of things in the core, so they may graduate with some idea of what their chosen profession is all about. Still other colleges offer an expanded core to alleviate the intensive cramming of knowledge in small isolated packets, and then allow the student more freedom to elect technical courses of his own choice.

The trend in the engineering colleges is towards more humanities courses. Personally, I do not subscribe to this. It tends to limit still further the student's education in engineering. A smattering of various types of humanities courses in the four years of the man's life, when he is studying intensively on technical work, does not seem to me to be worth the sacrifice. In the optional program, the core is so tight that it is extremely difficult to include photogrammetry into the core itself. Thus, photogrammetry will tend to be a technical elective. In the general program, photogrammetry stands a much better chance of being adopted as a required course, not perhaps to the extent I have outlined, but maybe in combination with a course in advanced surveying.

In the expanded core program, photogrammetry should be included in the surveying course if possible, or offered as a technical elective in which instance more extensive coverage will be permitted.

A course in the interpretation of aerial photographs for information concerning drainage, sources of construction material, sources of minerals, composition of soils, geological structures, slopes and gradients, population distribution and the like, would serve to greatly expand the facilities of those students interested in hydraulics, soil mechanics, foundations, highway location and design, irrigation and mining. Such a course, however, must assume that the students have an adequate knowledge of engineering geology, geomorphology, structural geology and agronomy; otherwise the interpretation of aerial photographs in these areas is not too effective.

Satisfactory introduction to interpretation can be effected by including in appropriate courses the individual facets of the earth sciences. For example, in a course for irrigation students or for those interested in hydraulics, the interpretation of photographs for slopes, gradients and drainage can be taught effectively by first introducing the basic principles of this phase of geology. Or, for example, a discussion of the interpretation of photographs for soil types, for the benefit of students in soil mechanics or highway design, can be made a part of another course in the particular specialty following a résumé of the physiographic regions of the country, their general structure, parent rock, climate and predominant soil types.

Teaching photo interpretation requires more personal experience on the part of the teacher than does teaching photogrammetry. Photogrammetry is based on the exact sciences of physics and mathematics, while photo interpretation is based on experience and judgment on the part of the interpreter in addition to the exact sciences. Thus, to offer photo interpretation in the civil engineering curriculum poses more of a problem than does photogrammetry especially when no work is being done in this field in the way of research on the part of the faculty.

We have at our disposal the benefit of the experience of those who are engaged in photo interpretation as applied to civil engineering in the form of papers and articles appearing in PHOTOGRAMMETRIC ENGINEERING and other scientific and technical organs. However, this type of education does not carry over in the way which the literature on photogrammetry does. I believe that educators must realize this when they go out beating the bush for teachers in the subject.

In closing I will briefly discuss photogrammetry and allied surveys as they relate to state licensing and state registration of civil engineers. State registration of civil engineers was first required in this country to provide protection against fraudulent and unreliable maps. Thus, it was recognized that surveying and mapping was embraced by the civil engineering profession. Land surveying was also recognized in some states as being a part of the practice engaged in by civil engineers. Now the big debate is whether photogrammetric mapping is or is not a function of civil engineering. In the United States, this method of mapping was not developed by universities in their engineering colleges except in a few cases. It was developed practically in spite of the colleges' failure to do anything with photogrammetry. And to this day, the situation has not changed substantially.

Admittedly, the situation is improving; nevertheless, graduating civil engineers on the whole cannot lay claim to photogrammetric mapping as a part of their profession by virtue of their education alone.

The practicing of photogrammetric mapping by non-registered persons or corporations is being argued in the courts in one Western state. A bill at this moment is before the same state's legislature to exclude photogrammetric mapping and all necessary surveys incident to the mapping, from the civil engineer and land surveyor code.

If photogrammetry is to be a function of civil engineering, then it should be a part of every civil engineering curriculum.

PHOTOGRAMMETRIC TRAINING FOR THE TECHNICAL FORESTER*

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THE magnitude of the importance of photogrammetric training to the professional forester is a fact so well substantiated and documented that any attempt here to provide further verification would be purely repetitious. That forestry schools are, in general, cognizant of this fact is borne out by a recent survey to which 25 of the 26 accredited United States forestry schools responded. This survey revealed that all of these 25 schools will incorporate photogrammetric training in their respective curricula this coming academic year. In fact, they are already doing so. The mere presence of such training in a professional forestry curriculum, however, is not enough in itself. What is really pertinent is whether or not this training is geared to the actual needs, now and in the future.

What may we reasonably define as our educational requirements in photogrammetry for the future? If assumed that our needs will continue to increase, it seems logical to believe that our training will have to be expanded beyond a concentration on forest inventory applications, to which most of us presently confine ourselves, and to enter to an increasing extent into photogrammetric applications in the fields of silviculture, forest management, forest influences,

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