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The Teacher's Dilemma

Based on an analysis of present needs, a suggested curriculum for photogrammetry is presented.

Among educators there is debate on how and where teaching is to take place, and how (and whether) the learning is to be evaluated. On the question of "what" should be offered to the students and "how," everyone seems to have his own idea. The programs and curricula in the field of surveying in institutions indicate their independent thinking which is fully justified. Curricular decisions clearly fall in the domain where the faculties have undisputed responsibility and prerogative, and irregularities do exist.

Abstract: *The paper analyzes the needs of the world of mapping corresponding to the levels of required photogrammetric education, nationally and internationally, briefly studies future trends, and various ways of structuring course work patterns. The merits and demerits of various approaches are discussed. A pattern of courses is presented, emphasizing conventional photogrammetry, separating instrumentation, adjustment theories, and administration problems, and concluding with non-conventional photogrammetry.*

Photogrammetry is defined by the American Society as "the art, science and technology of obtaining reliable information about physical objects and environment through processes of recording, measuring and interpreting photographic images and patterns of electromagnetic and acoustical radiant energy and magentic phenomena."

Although photogrammetry should (or could) be considered as an independent discipline (because of the range of its application, the manpower involved, and the annual turn-over), it still is an important component in the complex system of modern surveying and mapping.

The American Society of Photogrammetry admits that "the principal application of photogrammetry consists of the derivation and production of topographic maps and surveys based on measurements and information obtained from aerial photographs." Therefore, in this context, an attempt will be made to address ourselves from the point of view of the survey teacher in photogrammetry.

In terms of the level of education, proficiency, etc., as in other fields of applied science or engineering, one can group the photogrammetrists in the following three categories: (1) Photogrammetry *Technicians* (e.g., plotter operators) with post-high school education of one-two years; (2) Photogrammetry *Professionals* with post-high school education of three -four years; and (3) Photogrammetrists with *Graduate* level education, with college education of five years or more.

It is necessary, to know the existing and desirable ratios of the number of persons between these categories. Brandenberger[1] reported to the International Society of Photogrammetry (ISP) in 1972 that from the available information on a world-wide basis there exists (or is requested as ideal) an average ratio between the three categories of 5.4: 2.9: 1. For individual countries the reported ratios show considerable fluctuations varying between the limits 4: 3: 1 and 20: 3:1.

The rapid increase of surveying activities requires an appropriate educational program based on realistic projections. Fortunately in this country the American Congress on Surveying and Mapping conducted studies in this respect (see McNair[2]) and found that for the period 1971-75, annually several hundred professional photogrammetrists and nearly twice as many technicians will be needed. Obviously, course curricula must take into account the primary need of these two groups and the current "state of the art" as well as future trends.

During the years ahead, an unprecedented demand for all types of topographical and terrain information in a wide variety of formats is expected. The various conventional topo maps and conventional procedures of mapping are no longer fully adequate. Cartographic operations are being automated and the use of photo-maps and orthophotomaps is gaining more acceptance. Automated data banks featuring rapid storage, retrieval, and display are being sought. This demand must yield acceptable supply. Furthermore, digital terrain data are continually improving and the uses have already expanded with the fields of highway, vehicle design, land-use models, etc. The mapping community and society-at-large would benefit tremendously if efforts are devoted to four-dimensional (*X*, *Y*, *Z*, Time) and five-or more dimensional (*X*, *Y*, *Z*, Time, Type of terrain point, etc.) photogrammetry.

The modern photogrammetric map maker is no longer satisfied with the instrumental photogrammetry that was considered a major break-through during the 1940's and 1950's, or with the computational photogrammetry of the 1960's. More automated equipment for more universal applications are demanded and a great potential now exists for systems like the analytical plotters.

Apart from the conventional (frame) photogrammetry, an increasing use of nonconventional (remote sensing, close-range, etc.) systems is being made. These use television and electronic communication techniques — valuable new tools in surveying and mapping efforts.

Furthermore, in this respect, reference can be made to replies obtained internationally to a set of questionnaires posed by the ISP Working Group on Education (see Brandenberger[1]). To quote Brandenberger, ". . . it follows that in the course curricula more emphasis must be made in the future on such items as automation, electronic systems, use of computers, remote sensing systems, photo-interpretation . . ."

It is not enough to solve the mapping problems. Even there, solution is a "why" and "how" problem; the realization of "what" precedes it. The teacher must not forget this. He should be urged to put more emphasis on "what" and "how" while teaching the technician and on "why" while teaching the professional. At the graduate level, the teacher must adopt special attitudes for himself and his students.

For purposes of discussion one may characterize certain activities as "Instruction" and others as "Research"[3]. "This formal distinction should not obscure the fact that in a university the two are closely related." The intimacy of the connection between research and instruction should be most visible at the graduate level of instruction where both the teacher and students become learners. For undergraduates, a contact with research can provide excitement and motivation to learn more.

This indicates that modern photogrammetry is complex and it cannot be taught quickly. Let us, then, take a hard look at the subject in order to help the teacher bring the right message in the most appropriate way in keeping with the fundamental concept of tri-variate need of efficiency (Figure 1).

The science of photogrammetry can be considered in terms of various divisions under different criteria as follows:

A. Basic working procedures.
   1. Data Acquisition
   2. Data Processing
   3. Data Analyses and Applications

Such classification tends to be rather theoretical and yet very revolutionary and not in keeping with the traditional approaches to teaching surveying. Therefore, I, as a teacher, would not be in favor of such a classification. In terms of various available techniques and possibilities, study courses based on this classification would be rather complex to comprehend.

B. Approaches to various solutions of problems:
   1. Graphical
   2. Analogical (Empirical-Instrumental).
   3. Computational (Analytical?)

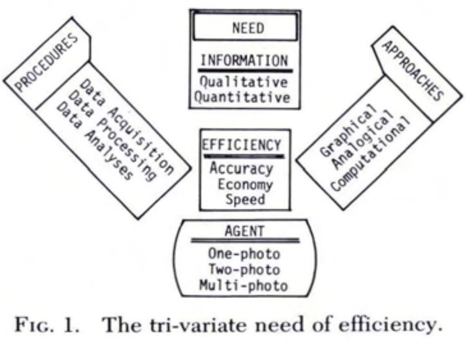

FIG. 1. The tri-variate need of efficiency.

This classification follows the historical conservative growth pattern. Some institutions associate the terms "Analytical" or "Computational" with their course titles without their being really so.

C. Basic units and corresponding mathematical developments:
   1. Single-photo
   2. Two-photo (stereo)
   3. Multiple-photo (n-photo, aero-triangulation).

This classification is in keeping with the handling of information and data (e.g., two-dimensional or three-dimensional; points, distances, or angles) as well as instruments and agency requirements. It is very logical for data processing and data analyses, development of their theories, and final applications.

D. Areas of the science followed by the International community (ISP):
   1. Primary Data Acquisition (Commission I)
   2. Instrumentation for Data Reduction (Commission II)
   3. Mathematical analyses of data (Commission III)
   4. Topographic and Cartographic Applications (Commission IV)
   5. Non-topographic Photogrammetry (Commission V)
   6. Economic, Professional and Educational Asepcts (Commission VI)
   7. Interpretation of Data (Commission VII)

This classification is very logical from the society administration point of view but is not relevant to teaching of surveying and mapping, in keeping with the various levels of instruction.

E. Other possible classifications in accordance with published (text) books in which most of the authors have followed a pattern similar to the concept "C" above.

The educator must not follow any classification that is not logical to the understanding of the subject matter, and does not help develop the courses for eventual in-depth studies. Several colleges and institutions in this country and abroad have developed courses and study programs in photogrammetry and allied areas within surveying and mapping, while others are planning for newer programs to be established. Some of the existing ones are impractical, some are confusing, and others unsatisfactory. This author is not happy with the program at The Ohio State University, and none of the existing is perfect. A unified system of instruction and course pattern is necessary; clearly, this is lacking. A course pattern in photogrammetry for colleagues to scrutinize and consider is proposed, but first some words of caution.

The teacher must not forget that today's college students are in many cases already well-informed in a variety of areas. Also, apart from the classroom lectures, there are several means by which one acquires knowledge, e.g., the mechanized instructions which can supplement or complement such classroom teaching. The role and the background of the faculty must be re-examined. These two are merely components within a large and complex group of considerations which also involve cost accounting, the demands of administration (trustees, regents, etc.), and the needs of the society and the students. On the other hand, nothing interesting will happen until each component is examined separately and is properly related to the bureaucratic and socio-economic complex that education has become.

It is true that we must change if we want to progress or improve. But it must not be forgotten that mere change is not progress. It is complex and each one of us has his own construction of the world. It is in this spirit that the following ideas are submitted.

Suggested Courses or Divisions within courses (see Appendix for details):

1. Fundamentals in Photogrammetry
2. Single-image Photogrammetry
3. Stereophotogrammetry
4. Multiple-image Photogrammetry
5. Instrumentation in Photogrammetry
6. Theory of Errors and Adjustments
7. Photogrammetry in Practice
8. Non-conventional Photogrammetry

The first five subject areas may be considered required for every student in surveying. The first establishes the fundamentals and philosophy of measurements, etc. Divisions 2, 3, and 4 would develop the basic theories, discuss various techniques of data acquisition, data processing and data analyses, etc., in a logical sequence. Instruction on various instruments (division 5) could be made during 2, 3, or 4 as found necessary and relevant. However, it is better to separate and discuss the instruments after the background theories have been presented when application is better appreciated. Division 6 would present finer theories of errors and adjustment computations ideas, desirable for professionals and graduate students. Division 7 would be the course on job planning, etc., meant for future executives and supervisory personnel and it will be best appreciated if a student takes this course in the end. Division 8 (non-conventional photogrammetry) should be in keeping with the future trend to inspire the potential researcher and to help establish regular courses later.

The above gives a logical spread through the entire spectrum of photogrammetry. In deciding the required(s) and elective(s), levels of the courses, etc., one has to consider the circumstances, program philosophy, etc.

In an institution where the program could be elaborate, catering to the requirements of the technician, professional, and students at higher levels, the program should be progressively flexible. Basic mathematics and physics would provide the most important base. Later, as the student's knowledge progresses, he may obtain ideas from other fields such as geodesy, cartography, computer science, statistics, etc. Thus, depending on his advancing requirements and interest, he would advance progressively. As he proceeds, he would pick up newer ideas from other fields.

A rigorous and thorough set of courses has been outlined in the belief that the revision of the curriculum should take into account assumptions about the sort of society the graduate will live in. This includes recognition of such trends as have been already noted. The reader's list might differ a little from this but would probably lead to a similar conclusion, viz., the need to cultivate experience with the wide variety of photogrammetric techniques for analyzing and coping with human dilemmas. The formerly dominant ideal of civil engineering — understanding the Euro-Asian-American scientific heritage — becomes only one constituent element in the redefined ideal.

References

1. Brandenberger, A. J.; "General Report of the Working Group 'Education'," Report of Commission VI, *International Congress of Photogrammetry*, Ottawa, 1972.
2. McNair, Arthur J.; "Surveying Education at the Crossroads", *Surveying and Mapping*, vol. 29, No. 3, Sept. 1969.
3. Ohio State University; "Directions for the Future", Report of the Centennial Commission on the Future of the Ohio State University, Columbus, Ohio 1972.

Appendix

Suggested Curriculum

1. Fundamentals in Photogrammetry

I. Introduction
- A. Purpose
- B. History and Development
- C. Major Problems in Photogrammetry
- D. Scope of Applications

II. Principles of Geometric Optics
- A. Fundamentals of Optics
- B. Lens Aberrations
- C. Other Optical Characteristics

III. Photography and Photographic Material
- A. Sensitometric Properties
- B. Filters
- C. Emulsion Carriers (film, glass, paper)

IV. Camera
- A. Design Parameters
- B. Various Types
- C. Associated Auxiliary Equipment

V. Physical Influences
- A. Atmospheric Refraction and Earth's Curvature
- B. Film Deformation
- C. Lens Distortion

VI. Stereoscopy
- A. Natural and Artificial
- B. Stereograms
- C. Plasticity and Stereopower

History, major problems, scope of applications, geometric optics, photography and photographic material, camera, physical influences, and stereoscopy.

2. Single-Image Photogrammetry

I. Coordinate Transformation
- A. Linear
- B. Affine
- C. Projective (2- and 3-dimensional)

II. Central Projection
- A. Photograph and Map
- B. Cross Ratio (four-point method)
- C. Projection of Points, Lines, Angles, Grid

III. Principles of Orientation
- A. Interior Orientation
- B. Exterior Orientation
- C. Space Resection and Orientation Matrix (collinearity condition)

IV. Geometric Considerations
- A. Vertical Photo, Flat Terrain
- B. Tilted Photo, Flat Terrain
- C. Tilted Photo, Rugged Terrain

V. Rectification
- A. Specialized Formulas
- B. Procedures (analog and digital solutions)
- C. Photo Map (also mosaic and ortho photo-mosaic)

Coordinate transformation, central perspective, principles of orientation, geometric considerations, and rectification.

3. Stereophotogrammetry

I. Geometric Considerations
- A. Conjugate Rays and Basic Differential Formulas
- B. Parallaxes (*X*, *Y* or total)
- C. Model Coordinates

- II. Orientation Concepts
  - A. Relative Orientation (coplanarity condition)
  - B. Scaling (Scale restraint condition)
  - C. Absolute Orientation
- III. Representative Applications (analog and digital)
  - A. Model construction (space intersection)
  - B. Model Scanning
  - C. Plotting
- IV. Model Errors and Analysis of a Deformed Model
  - A. Model Error in Relative Orientation
  - B. Model Error in Scaling
  - C. Model Error in Absolute Orientation
- V. Quality Control in Model Orientation
  - A. Weighting of Observations
  - B. Comparison of Methods of Orientation
  - C. Precision of Model Coordinates
- VI. Critical Surfaces
- VII. Convergent Photography
- VIII. Orthophoto

Differential formulas, parallax formulas; relative and absolute orientation; model errors; quality control in model orientations; critical surface; convergent photography; orthophoto.

4. Multiple-Image Photogrammetry

- I. Strip and Block Formation
  - A. Aeropolygon (aeroleveling, etc.) Conception
  - B. Independent Model
- II. Error Propagation
  - A. Due to Physical Influences
  - B. Due to Operational Influences
  - C. In Strip and Block
- III. Adjustment (graphical, mechanical, analytical)
  - A. Strip
  - B. Block
- IV. Digital Methods
  - A. Strip and Block Formation in Various Approaches
  - B. N-Photo solution (all parameters treated as observed)
  - C. Representative Applications (development of normals, results)
- V. Use of Auxiliary Information
- VI. Special Cases
  - A. Independent Geodetic Control
  - B. Partial Control Extension (radial triangulation, stereo templet, ITC — Jerie Analog, etc.)
- VII. Accuracy and Economic Considerations

Spatial photo-triangulation, analogical and analytical; strip and block triangulations; error propagation; use of auxiliary data; independent geodetic control; partial control extension; accuracy and economy considerations.

5. Instrumentation in Photogrammetry

- I. Introduction, Basic Elements Used in Instruments
  - A. Optical Parts
  - B. Mechanical Parts
  - C. Electrical Parts
- II. Single-Image Instruments
  - A. Rectifiers
  - B. Sketchmaster Type
- III. Double-Image, Simple Instruments
  - A. Stereoscopes with Scales and Bars
  - B. Stereometer Type
  - C. Stereosketch and Orthographic Types
- IV. Double Image, Projection Instruments, General Considerations
  - A. Basic Systems
  - B. Interior and Exterior Orientation
  - C. Primary, Secondary (etc. axes)
  - D. Zeiss Parallelogram
- V. Optical Projection Group
- VI. Mechanical Projection Group
- VII. Photo-Goniometer Group
- VIII. Instruments in Computational Photogrammetry
  - A. Radial Triangulators
  - B. Comparators (mono and Stereo)
  - C. Analytical Plotters
- IX. Use of Stereo-instruments as Comparators
- X. Evaluation of Instruments
  - A. General
  - B. Testing and Adjusting
  - C. Mathematical Modelling for static and dynamic performances.

Introduction to instruments used in photogrammetry. Single, double, and multi-image types; stereoplotter, comparators, and analytical plotters; evaluation, testing, and adjustment of instruments.

6. Theory of Errors and Adjustments

Note: This not being strictly photogrammetry, the details are not presented here. This subject area can be combined with Error Theory and Adjustment ideas in Geodesy, Cartography, etc.

7. Photogrammetry in Practice

- I. Introduction; Classifications
  - A. Topographical, Non-topographical
  - B. Single-Image, Double-image, Multi-image
  - C. Graphical, Analogical, Analytical
- II. Flight Planning in Aerial Photogrammetry
  - A. Single-image and double-image
  - B. Instrumental considerations
  - C. Accuracy considerations
  - D. Flying Height and Base-height Ratio
  - E. Procurement of Photographs, Contracts
- III. Station Project in Terrestrial Photogrammetry
- IV. Determination of Geodetic Data in Terrestrial Photogrammetry
- V. Determination of Geodetic Data in Aerial Photogrammetry
- VI. Signalization of Control Points
- VII. Compilation of Maps

VIII. Efficiency Assessment in Photogrammetry
IX. Economic Considerations, Cost Computations, Planning
X. Preparation of Technical Reports, Research Proposals, etc.
XI. Special Applications: (representative)
  A. Geological
  B. Cadastral
  C. Highway
  D. Close-Range
  E. Ballistic
  F. Space

Planning for aerial, terrestrial, and close-range photogrammetry jobs; ground control and signalization; map compilation, efficiency assessment; economic considerations; technical writing; various applications of photogrammetry.

8. NON-CONVENTIONAL PHOTOGRAMMETRY

I. Strip Photography
II. Panoramic Photography
III. Weather Satellite Photography
IV. Ranger, Surveyor, Lunar Orbiter, ERTS, Skylab, etc. Systems
V. Electron Microscopy, Scanning and Emission Types
VI. Hologrammetry
VII. Others

Studies in strip, Panoramic, and weather satellite photography systems; Ranger, Surveyor, Lunar Orbiter, etc. systems; electron microscopy and hologrammetry.

Report

THE UK PHOTOGRAMMETRIC SOCIETY BIRMINGHAM WEEK-END SYMPOSIUM 1975

A highly successful week-end symposium was held by The Photogrammetric Society (United Kingdom) on the campus of the University of Birmingham from Friday, April 18 to Sunday, April 20, 1975. The meeting was attended by 114 persons, including 7 from overseas (1 from U. S.). ISP commissions III and V actively participated in the program through their respective presidents.

There were six technical sessions, ranging from 60 to 105 minutes in duration. Two sessions were held on Saturday morning, two on Saturday afternoon and two on Sunday morning. Most participants arrived on Friday evening and the meeting dispersed after lunch on Sunday.

A varied yet cohesive program was arranged by the Technical Committee under the able chairmanship of Mr. D. W. Proctor. The topics of the six sessions were:

Session 1: "The Society, the Profession, the Future" (panel discussion on questions from the floor)
Session 2: Aerial Triangulation (2 papers)
Session 3: Non-Topographic Photogrammetry (2 papers)
Session 4: Non-Topographic Photogrammetry (panel discussion and questions from the floor)
Session 5: "Sixty Years of Transition from Manual to Automatic Operations" (1 paper)
Session 6: Future Needs in Instrument Design (panel discussion and questions from the floor).

All sessions were of a high technical level with ample time allocated to discussion. The discussion was uninhibited and extensive, with follow-up questions in many cases. Such meaningful and unhurried discussions are well worth providing time for in ASP meetings.

Saturday evening featured a dinner followed by a delightful and most enjoyable light entertainment, both musical and topical in nature.

Following discussion of his paper on Sunday morning, Gen. R. Brown was presented with an inscribed silver memento on the occasion of his retirement from the Council of the Society and his approaching 80th birthday. The warmth with which the presentation was made and the enthusiastic expression of approval by the audience reflected the high esteem and unique affection which General Brown enjoys throughout the international photogrammetric community.

A week-end technical meeting of this type provides a vehicle for extensive technical discussions in a relaxed sociable atmosphere conducive to informal exchange of ideas. ASP regions, and possibly also ASP Divisions, might wish to try this efficient and most enjoyable concept of meetings.

—H. M. Karara
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