

*Educational and Research Activity in Photogrammetry at the Massachusetts Institute of Technology**

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ABSTRACT: *During the past several years, the Department of Civil and Sanitary Engineering at the Massachusetts Institute of Technology has been expanding its activities in photogrammetry and aerial surveying. The educational program has been strengthened at both the undergraduate and graduate levels to accommodate a wide range of interests and activities. Particular attention is given to theoretical and applied photogrammetry as related to the civil engineering profession.*

In addition to the educational activity, the Institute has embarked on a major sponsored research program in photogrammetry through the support of the Massachusetts Department of Public Works and the U.S. Bureau of Public Roads. The majority of the research activity is devoted to photogrammetric and electronic computer systems for new approaches to highway engineering.

The purpose of this paper is to describe the educational program, laboratory facilities, and research activity in photogrammetry at M.I.T.

EDUCATIONAL PROGRAM

AS A result of the growing professional and technical importance of photogrammetry in civil engineering practice, the Department of Civil and Sanitary Engineering at the Massachusetts Institute of Technology has embarked on a program to develop increased educational opportunities for students with an interest in photogrammetry. The teaching of photogrammetry is by no means a new development at M.I.T. The subject has been taught by the Civil Engineering Department for over 20 years and the Photogrammetry Laboratory was established in 1946. The new program is one of increased emphasis and activity in this field.

Although the educational program in photogrammetry at M.I.T. is broad and flexible to accommodate a wide range of interests and activities, the engineering aspects and civil engineering applications tend to be emphasized. This is to be expected since the program is operated by and draws most of its students from the

Civil Engineering Department. It is felt that this emphasis on photogrammetric *engineering* is healthy since engineering applications offer one of the greatest potentials for further development of the field of photogrammetry. In addition, professional opportunities are increasing for young engineers with a background in photogrammetry.

The educational activities in photogrammetry at the Institute take many forms to accommodate the range of student interests. As part of the required undergraduate work in surveying, all of the civil engineering students receive approximately 10 hours of lecture and 24 hours of laboratory instruction in photogrammetry during the sophomore year. This treatment is devoted entirely to a theoretical development of basic principles, and the presentation of photogrammetry as a method of making spatial measurements. Photogrammetry is introduced at this early point because it is an excellent vehicle for introducing many of the basic

* Presented at the Society's Semi-Annual Convention at St. Louis, Mo., March 3, 1957.

problems and principles involved in making physical measurements.

In the first term of the senior year, an undergraduate course in photogrammetry is offered on an elective basis. This course is a rigorous introduction to theoretical and applied photogrammetry for students with a special interest in the subject. The course must serve two types of students. It serves as a basic course for those students who plan to pursue additional studies in the subject on the graduate level, and as a terminal course for those students with a professional interest in such fields as highway engineering. The course is also taken by graduate students who did not take an undergraduate course in photogrammetry.

In addition to the undergraduate course in photogrammetry, the interested student is afforded an opportunity to write his bachelor's thesis in photogrammetry. The undergraduate thesis is an excellent educational tool and can be quite stimulating and valuable to the student. In the last two years, eight students have elected to write their undergraduate thesis on a subject in photogrammetry. Undergraduate students are also often employed as student assistants on sponsored research projects of the Photogrammetry Laboratory. Such employment has educational value as well as giving financial assistance to the student.

Graduate activity in photogrammetry at the Institute is quite new. No formal or extensive program is contemplated since the number of students interested in graduate work in such a field will always be relatively small. However, it is definitely planned to offer graduate educational opportunities and to accommodate the degree of student interest which may develop. Instead of attempting to offer a number or sequence of formal graduate subjects in photogrammetry, course work is handled on an informal and individual basis through the medium of a "Special Studies in Photogrammetry" graduate subject. The graduate program of an individual student may then be tailored to accommodate his particular interest and for the graduate degree toward which he is working. He may register for the special studies course the number of times and for the number of units of credit necessary for him to accomplish his graduate program. Such an approach to graduate work in

photogrammetry is quite flexible and offers many advantages. One major advantage is that it permits graduate activity in a field which otherwise could not be justified. The success of such an approach depends to a large degree on the caliber of the students and the degree of their enthusiasm for the subject since they are subject to considerable self-discipline even though they are working closely with the instructor.

The thesis is of course a very important part of the requirements for any graduate degree. For the master's degree at M.I.T., the thesis accounts for approximately one-third of the total requirement. Hence, the special studies course and a thesis in photogrammetry permit the student to devote approximately one-half to two-thirds of his graduate work to studies and activities in photogrammetry if he so chooses. The balance of his work would be in related subjects in physics, mathematics, and civil engineering. The graduate student is afforded an opportunity not only to take supporting subjects in other departments at M.I.T., but also to take advantage of selected subjects offered at nearby Harvard and Boston University.

Since M.I.T. awards degrees by departments, students studying photogrammetry at the Institute receive their advanced degree in civil engineering or the department in which they are registered. It is interesting to note that a doctorate in mechanical engineering was awarded several years ago based on a thesis in photogrammetry. This is a good example of the flexibility of the Institute's graduate activity. M.I.T. also has an agreement with the International Training School for Aerial Survey at Delft, for the interchange of credits.

In addition to the undergraduate and graduate education activity, during the summer of 1957, the Institute initiated a special summer course in photogrammetric engineering for men engaged in professional practice. The course was quite successful, attracting 55 outstanding engineers from government, private and industrial organizations engaged in photogrammetric practices. The M.I.T. staff was augmented by seven prominent photogrammetric engineers from other institutions and organizations who served as guest lecturers. It is felt that such a course can be a valuable educational contribution to the practicing

photogrammetric profession and probably will be repeated in future summers.

LABORATORY FACILITIES

Adequate laboratory equipment and facilities are of course essential for educational and research activity in photogrammetry. The Photogrammetry Laboratory was initially equipped in 1946 through the generosity of Senator Thomas C. Desmond of New York. During the past two years, Michael Baker, Jr., Inc., Consulting Engineers of Rochester, Pennsylvania, has made substantial contributions to the Laboratory through the donation of stereoplotting equipment. Such equipment manufacturers as Bausch and Lomb, O.M.I., and Bendix Computer have also cooperated in augmenting the equipment available for research. The Laboratory occupies three rooms devoted to staff office, research laboratory, and student laboratory. The principal photogrammetric equipment includes Kelsh, Balplex, and Multiplex stereoplotters. A Nistri Electro-Coordinatometer and Electro-Coordinatograph are being used for instrumentation research. (Figure 1). A complete automatic digital output system has been built to operate with the coordinatometer and the Kelsh or Balplex plotter. Output devices available in the Laboratory include an Underwood Servotyper, Bendix tape punch and I.B.M. 526 printing summary card punch.

The Laboratory is equipped with many other photogrammetric instruments such as parallax bars, stereocomparagraphs, contour finder, Multiscope, radial-line plotter, sketchmasters, rectoplanograph, plotting board, templet punches, mechanical templet set, mirror and lens stereoscopes. (Figure 4) A calibrated meter bar, micrometers, Ames dials, drafting equipment, electronic equipment, and limited workshop facilities are also included. The total value of the instruments and equipment currently being used by the Photogrammetry Laboratory is approximately \$45,000. For related fieldwork, complete surveying equipment including Wild, Kern and Zeiss levels, theodolites, and subtense bars are available from the surveying laboratory. Although a photographic laboratory is not maintained, extensive facilities are available through the M.I.T. Photographic Service.

The Laboratory has a good library of

aerial photographs, mosaics, diapositive plates, photogrammetric maps and related material. Most of this material has been donated by private firms and government agencies and contribute materially to the educational program. In addition an attempt is being made to develop a complete library of photogrammetric literature for student and staff use.

The Photogrammetry Laboratory at M.I.T. is fortunate to have access to and assistance from many other well equipped laboratories at the Institute and in the immediate area, particularly in the photographic, instrumentation, electronics, and computer fields.

RESEARCH PROGRAM

In a technical and professional field such as photogrammetry, it is almost imperative that educational activity be conducted in an environment of creative research. The development of a sponsored research program has been a very important stimulus in expanding the photogrammetric activity at M.I.T. Each graduate student in photogrammetry at the Institute is also a member of the research staff, illustrating the close relationship of research activity and education activity. The contract value of the research activity of the Laboratory is now approximately \$190,000.

The major research project of the Photogrammetry Laboratory is sponsored by the Massachusetts Department of Public Works in cooperation with the Bureau of Public Roads. This project is devoted to exploring new methods and applications of photogrammetry to highway engineering. The scope of the contract is quite broad and is not limited to narrowly defined technical problems. The research staff is given the freedom to explore new ideas and concepts of both short-range and long-range value without undue restriction. Therefore, although considerable development work is underway, an opportunity is afforded for the staff to apply its talents to creative activity of a type most suited to university research. The Laboratory is very fortunate to have sponsors which recognize the value of permitting such freedom in conducting research.

The major area of activity currently underway is related to the development and utilization of an integrated system of photogrammetry and electronic computers for highway engineering problems. Instead

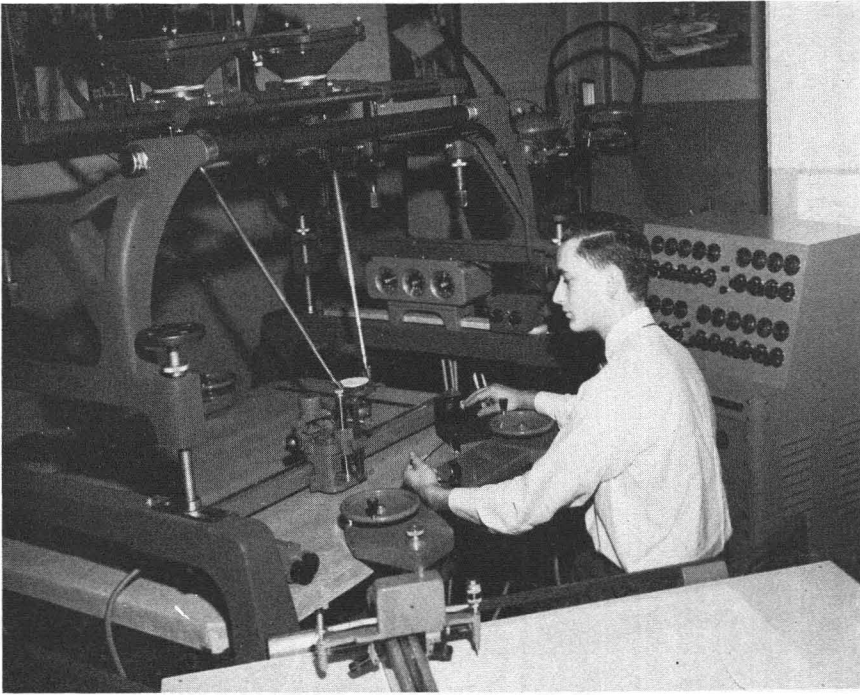


FIG. 1. Partial view of laboratory area showing modified Kelsh Plotter, Balplex Plotter, and Nistri Coordinatometer units.

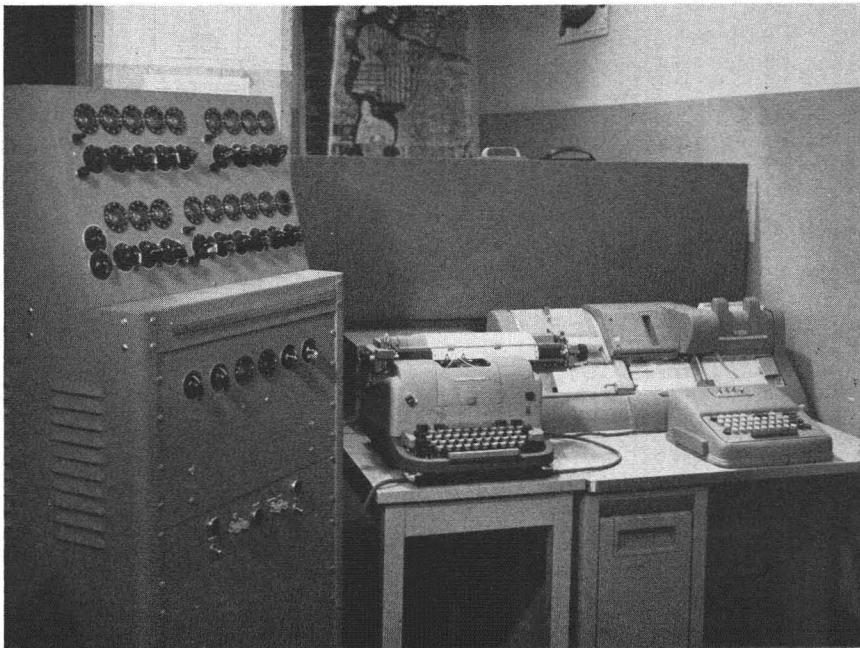


FIG. 2. Special automatic digital readout control unit developed in the Laboratory and electric typewriter and card punch for digital recording of photogrammetric data directly from the stereoplotter. The unit is also connected to a Bendix tape punch.

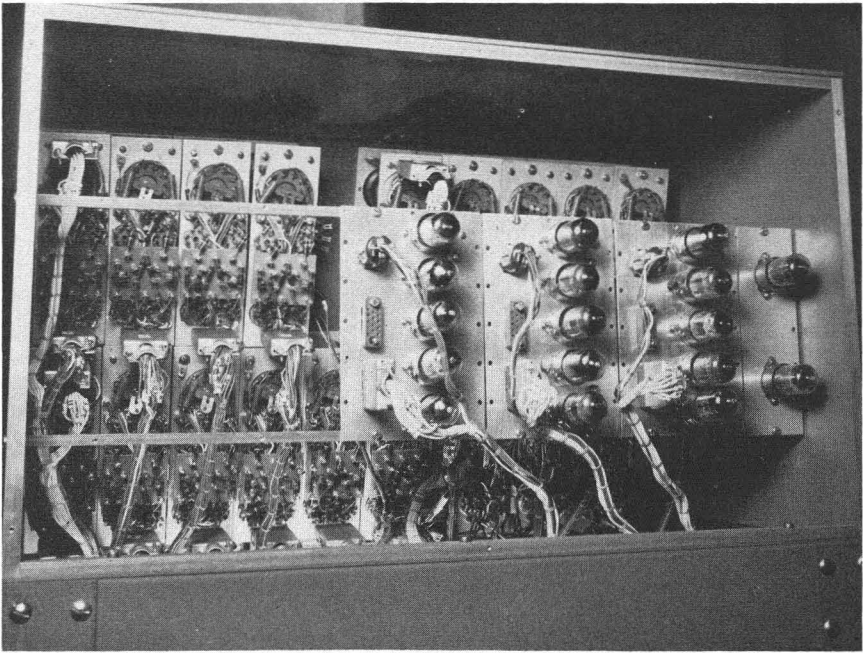


FIG. 3. View of interior of automatic readout unit showing electronic counting units.



FIG. 4. Partial view of laboratory area for student activity showing some of the small accessory type equipment. Not shown but included in this room are three units of Multiplex equipment for student use.

of working on the obvious approach of simply replacing the survey party by the stereoplotter for cross sections and the electronic computer for standard manual calculations, an attempt was made to develop an entirely new approach or concept of the highway location and earthwork problem. The principal motivation was to explore the possibilities of making fuller use of the potential capacity and efficiency of photogrammetry and electronic computers to procure, reduce, and process large quantities of terrain data. This led to the concept of a *digital terrain model*. With such an approach, a band of terrain is stored in digital form on a computer input material. The stored digital terrain model is arranged such that any highway alignment of interest within the digitized band can be analyzed for earthwork quantities by an electronic computer. With such a system it becomes feasible to think in terms of numerically evaluating a very large number of trial lines in order to converge more closely on the optimum solution. In addition, such a system offers very attractive scheduling possibilities in making efficient use of engineering time. The concept of using an electronic computer to analyze a digital terrain model has many other potential applications to engineering and military problems involving terrain considerations.¹

An operational system for using the digital terrain model approach for numerically evaluating highway location has been developed by the Laboratory and is now in experimental use.^{2,3} Three electronic computer programs required by the system have been completed by the project staff and are now in operation on the I.B.M. 650 electronic computer.⁴ It is planned to have the same programs coded for the Bendix G-15 general purpose electronic computer since there are many users of this computer in the highway field.

Considerable research work has been conducted on the subject of automatic digital output systems for stereoplotters⁵ and directional scanning techniques.⁶ A set of Nistri Electro-Coordinatometer equipment was installed in June and the Kelsh Plotter modified to accommodate the equipment and to permit rotation movement of the unit for directional scanning. A special experimental analog to digital converter system and automatic digital output system was designed last

spring and built during the past summer. This electronic system has many unique experimental features, which will permit research on several new approaches to integrating the stereoplotter and electronic computer.⁷

A closely related development to that of the digital terrain model is the concept of a *digital cost model*. In this case the z ordinate at each xy value has the dimension of dollars, such as the cost of building a unit length of highway through the area represented by the xy value. Such an approach would permit the computer to consider all other highway location factors which could be reduced to a cost figure such as the cost of right of way. The cost data on many of the location factors can be obtained by airphoto analysis. All metric data would be furnished by photogrammetric measurements including the digital terrain model. Such a concept was first proposed by the senior author in a paper published in *PHOTOGRAMMETRIC ENGINEERING*.⁸ Mr. Paul Roberts, a Research Assistant and graduate student at M.I.T., received the 1957 Bausch and Lomb Award for a paper on this subject.⁹ Research investigations on the digital cost model approach to highway location evaluation are currently underway. Although considerable work remains to be done before such a system can be considered perfected, many interesting ideas are being explored.

In addition to the highway research activities, the staff of the Laboratory have been engaged on such diversified problems as using photogrammetry to track and measure clouds and for determining the relative motions of the various bones in the human foot. The Church solution of the space resection problem has been programmed on the M.I.T. Whirlwind I electronic computer for aircraft tracking. A number of studies related to the digital terrain model concept are underway. For example, the influence of point density on the degree of approximation is being studied using an electronic computer program.

COOPERATION

The basic goal of the Photogrammetry Laboratory at M.I.T. is to contribute to the professional and technical advancement of photogrammetry. The most important possible contribution is to assist

in preparing young men for a career in photogrammetry. Secondly, an attempt is made to advance the state of the science and art of photogrammetry through basic and applied research, and finally through staff participation in professional activities. The same goals are fundamental to the program in photogrammetry at other educational institutions. The success of such programs depends in large part on the cooperation and backing received from public, private, and industrial organizations with an interest in photogrammetry. It is certainly in the interest of such organizations to see such programs strengthened and expanded. Assistance can take many forms such as (a) sponsorship of research, (b) equipment and financial grants, (c) direct aid to students, (d) literature, technical material, and teaching aids, (e) moral support by simple verbal or written expression of interest. Such assistance is earnestly solicited for those schools attempting to make a contribution to the future of photogrammetry. Finally, members of the profession can materially assist the future of photogrammetry by encouraging promising young men to study photogrammetry in college as a field of growing importance and exciting potential in this era of science and technology.

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KODAK WILL DEMONSTRATE APPLICATIONS OF COLOR PHOTOGRAPHY IN TRAVELING EXHIBIT

Eastman Kodak Company has announced that it will sponsor a color photography exhibit to be shown in a dozen major cities in April and May.

Schedules are now being planned for the show, which will be of particular interest to personnel in the fields of advertising, publishing, and photography itself and will include some of

the finest work in color being achieved today by commercial, industrial and press photographers.

In previous years the Kodak Color Show has been visited by as many as 20,000 men and women who purchase or use photography. The route of the last show in 1955 and in previous years was from west to east. The 1958 show, Kodak revealed, will have its formal opening in New York, then travel through the middle and far west.

Major emphasis in the displays will be on the versatile abilities of the color negative system, whereby one color negative can be used to make color prints, rear-illuminated transparencies, color slides and either orthochromatic or panchromatic black-and-white prints.

In each city the show will be open for one or two days in the ballroom of a major hotel. No admission will be charged.