THE LIMITATIONS OF SIMPLE STEREO-PLOTTING DEVICES*

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Introduction

IN PHOTOGRAMMETRIC ENGINEERING, vol. XII, No. 3 (Sept. 1946) Mr. Duane Lyon has an article entitled "Automatic Plotting Instruments—The Deville Type of Instrument." He describes a number of stereo plotting devices, of which some have been actually built and put to use while others have not reached the design stage; but all have the common feature of a fixed viewing system and the use of virtual images of a stereo pair of photographs for the operation of plotting directly from the photographs to a map. The article is of special interest to Canadian readers as Mr. Lyon uses the now classic invention of Dr. Deville (1) as the prototype of the devices with which he deals.

Among the increasing number of workers in the photogrammetric field there are bound to be some who have or will have ideas regarding the development of plotting instruments and I feel, after reading Mr. Lyon's paper, that a few remarks regarding the problems which have to be solved and the limitations imposed on first order, or simple, solutions of these problems may be helpful to potential inventors.

Basis of Discussion

At first glance the operation to be carried out appears to be a simple one, and it cannot be denied there is a wide field for simple stereo-plotters, if satisfactory ones could be developed. The application of photographs to mapping was foreseen as soon as photography became feasible; for the photograph is a perspective projection, and can be treated by the laws of perspective geometry. The apparent similarity of the appearance of roads and other features on a vertical air photograph to the appearance of the same features on a map, suggests that there should not be much difficulty—at least until the subject is studied a little more deeply. At the same time there are certain elementary conditions which should be satisfied; and it goes without saying that the more nearly a plotting instrument satisfies these conditions the more practical it is likely to be. It is suggested that the following rules are among those which should be kept in mind:

(1) To obtain strictly correct perspective resection, each photograph must be viewed or projected in such a manner that the images of all points maintain their correct relationship.
(2) When a viewing system containing lenses is used the limitations of the field of view and other optical properties must be considered.
(3) The eye, or any other lens, cannot be made satisfactorily to form a coincident image of near points which are at different distances from it.

These rules seem obvious, but some inventors of plotting devices do not appear to have heeded them to the necessary extent to obtain practical results. The rules, and some of the difficulties in stereo-plotting are treated in more detail below.

Factors To Be Considered in Stereo-Plotters

The Multiplex

The fulfilment of the rules just given is exemplified in the multiplex (which does not, however, belong to the class of instrument under discussion) where

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care is taken to project the photographs so that the light rays issuing from the lenses take the same relative paths as the corresponding incoming rays at the instant of exposure. The multiplex is, therefore, worthy of study by all potential inventors as giving an exact solution of the problem so far as the first principles are concerned. Unfortunately the apparent ease with which a *real* image is obtained in the multiplex and projected on to a screen may lead one to expect that it is a simple thing to obtain a virtual image in a stereo-plotter, where the photographs are viewed stereoscopically, and to introduce a mark in the neighborhood of the images for plotting purposes.[1]

Positioning the Photographs

From Rule One it is evident that in adjusting the photographs to yield an accurate stereo model in the virtual image type of plotter, any mechanical movement must take place by rotation about the perspective centres applying to the photographs when they are set up for observation. In the simplest case, this will be by rotation about the respective eyes of the observer. An exact solution of this requirement is usually difficult or impossible in a simple device. In the multiplex and in the expensive European plotting machines it is accomplished by mounting the photograph in a frame with the necessary degrees of freedom about the perspective centre. In the case of these machines somewhat elaborate optical and mechanical linkages become necessary to permit the photographs to be viewed stereoscopically even then, and despite this complication the simple laws of stereo projection are not always satisfied, as has been shown by Hotine (2). Some of the simplest plotting devices in actual use or proposed, fall very wide of the mark in the means for giving correct stereo fusion, and are therefore either inaccurate and necessitate continual adjustment as different portions of the photographs are viewed and/or are likely to be productive of considerable eystrain on the part of the operator.

Plotting Scale

It can be shown by drawing a simple diagram that if two stereo photographs be restored to their correct relative position, i.e. reconstructed for tilt, swing, principal distance, etc., and then viewed simultaneously, each by one eye, that the stereo model apparently seen will have a scale of b/B, where b is the distance separating the observer's eyes and B the air-base. For example, if the photographs could be re-established at the original camera stations, the rays passing through them from the perspective centres would intersect to form a stereo model coincident with the ground itself, i.e. scale 1 to 1. Consequently if rigorous adherence is made to perspective geometrical conditions and a stereo model is apparently seen by the eyes with a mark, e.g. the plotting mark of the multiplex, placed so as to "touch" the "ground" in the model, the plotting scale will be fixed at the one value, as the distance separating the observer's eye is constant. It also follows that in dealing with consecutive pairs of photographs difficulties will arise from the variations in B. The way in which the photographs are viewed, i.e. by the interposition of lenses, prisms, etc., will have no effect on b, as, for stereoscopic observation, the virtual images of the photographs must be formed immediately before the eyes for fusion to take place. Viewing the photo-

[1] In elementary text books on physics it is explained that in a real image formed by a lens or prism, the light rays actually pass through the image which will thus appear on the screen if placed at the position of the image; while in a virtual image the rays only appear to come from the position of the image, which is therefore subjective. Good examples are the image of a rod formed by the objective of a telescope, which is real, and the image of the same rod seen by the observer in looking through the eyepiece, which is virtual.

graphs from a closer principal distance will not change the plan scale—the two plumb points in the model will still be vertically beneath their respective eyes —but the variations in relief will be exaggerated; an effect which is apparent to anyone who has looked through a magnifying stereoscope.

In the multiplex, on the other hand, the "base" between separate projectors is adjustable to control the plotting scale and in the complex European plotting machines scale is governed mechanically by the use of the Zeiss parallelogram (3), which can be regarded, in this function, as a pantograph.

Reference Marks

The single floating mark seems to be the best to use with a Deville type plotter. There are difficulties in employing marks of the two component type, which can be attached to, or used in conjunction with a Zeiss parallelogram for scale control. Each component must then move in the plane of the respective photograph, or in the plane of the real image of the photograph formed by a lens system, before the virtual images are produced which give the stereoscopic fusion. This is easy to do with the complicated optical systems of the direct plotters, but not so readily adapted to simple applications of the Deville type unless fundamental principles are violated to a greater or less extent, with eyestrain seeming to be inevitable.

Limitations of Optical Viewing Systems

Some designers employ lenses as an aid in viewing the photographs and/or floating mark from a comfortable distance or with the intention of introducing scale changes. With fixed lenses the useful field of view over which good imagery is possible may be a serious handicap with the wide angle photographs now common. Where a train of lenses is proposed it is almost certain to be difficult or impossible to see every part of the overlap without moving the viewing device or the photographs. Small stops, sometimes inserted to give a wider range of focal distance may have the same effect, and, furthermore usually entail serious loss of illumination by curtailing the effective eye pupil. In any case an attempt to view at the same time, say a photograph and a reference mark, will fail, or cause severe eyestrain, if the system is not designed so the images of the objects seen at the same time fall at or nearly in the same planes.

In the multiplex short focus projection lenses of small aperture (giving it may be noted in passing, the problem of providing a very bright light source) are employed so that there is appreciable depth of focus at the plotting screen, and a mark on the screen will be visible together with the stereo image over a wide range of elevation differences. This is easier to accomplish with a projection device as a rule, than with the Deville type of plotter.

The Ideal Case

If vertical photographs could be taken without tilt a much simpler problem is presented. For stereo plotting in the case of such photographs, a simple optical system can be used with sharp imagery and absence of eyestrain. The photographs and/or semi marks (which are easily placed in the plane of the photograph or of a real image) can be coupled to a Zeiss parallelogram so that scale adjustment and plotting become easy.

After noting the difficulties presented by tilted photographs, which, if coped with under rigorous conditions, appear to result in a machine having all or most of the complications of the stereoplanigraph; or, if compromise is attempted, seem to result in eyestrain, inaccuracy, or unsatisfactory performance; the ques-

tion might be put as to whether photogrammetrists should not utilize some of their inventive ability in attempting to produce rectified vertical photographs at a reasonable cost.

Pioneers, who have the advantage of working on a problem before the solutions attempted produce a bewildering amount of material, can sometimes make a wise choice. In this regard it is interesting to observe that in the Brock process, one of the first to be developed for air photogrammetry, rectified photographs are produced in the office with a consequent simplification of the actual plotting operation.

Many of the compromises that have been adopted in our mapping offices and a great deal of the labour expended, arise from tilt errors and their treatment. If, therefore, the multiplex, or the Fourcade plotter (the model of which, intended for shipment to Canada, was destroyed in an air raid during World War II) or other device yet to be invented with other air or office equipment which may be developed or applied in the future, could be adapted to some process for the production of rectified prints, with which alone the mapper would then be concerned, improved over-all efficiency and a saving of much uncertainty might conceivably result.

The field in this and other matters seems unlimited and hence, also, are the opportunities for the genius of those who care to make photogrammetry their vocation.

Conclusion

Enough has been said to indicate the difficulties in constructing simple, but accurate plotting devices for stereo air photographs. While these difficulties should be studied they should not deter inventors. Often too-experienced workers fail to see the wood for the trees and non-orthodox means of advance have, more than once, made possible sudden jumps in the progress of pure or applied science. Hence any idea on stereo plotting must not be summarily dismissed until it has been shown to be impractical—using an actual trial if possible. It is hoped, therefore that these somewhat disjointed remarks will fulfil a constructive rather than a destructive role.

One final observation—any inventor of a mechanical or optical device is strongly recommended to make a model embodying the essential elements of his design. Much can be learned even from pieces of wood and string, properly used; and false or impracticable ideas corrected before unnecessary effort is wasted upon them.

REFERENCES

1. E. G. Deville. Transactions of the Royal Society of Canada, 8: 63–69. Ottawa 1902.
2. Hotine, M. Surveying from Air Photographs. Constable, London.
3. Field, R. H. The elementary principles of stereo plotters for air photographs. The Canadian Surveyor, Vol. V, No. II.

ANNOUNCEMENT

The service of a highly qualified aerial mapping photographer, experienced in operation and maintenance of the Fairchild K-17 series of aircraft cameras, is desired for a one year contract to work in Syria. The person selected must be capable of setting up and administering a complete aerial photographic laboratory, including the instruction of students in all phases of aerial mapping photography and related laboratory processes and techniques. Qualified persons who are interested may communicate direct with Major W. R. Buie, Syrian Legation, Washington, D. C.