The Potentials of the Photogrammetric Anaglyph[*,1]

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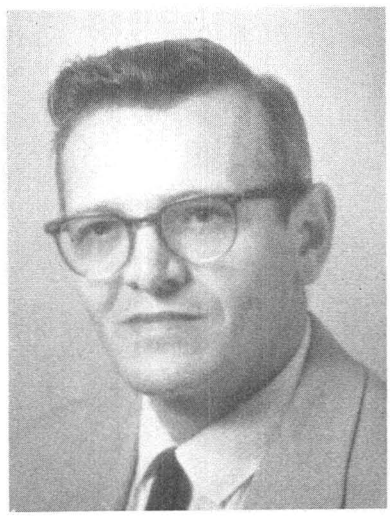
ABSTRACT: *This paper discusses the potential application of the anaglyph to the fields of photo-interpretation, relief-mapping and the stereoscopic compilation of topographic maps. A review is made of work previously performed with anaglyphs; results of the current investigation are given; anticipated problems are outlined, and tentative techniques and instrumentation are presented.*

INTRODUCTION

THE photogrammetric anaglyph is defined, for purposes of this paper, as physically a two-dimensional photograph which permits accurate measurement under three-dimensional viewing. It is a photograph of the projected, absolutely oriented, stereoscopic model. Thus, the original aerial photographs are rectified by the plotter to regain the attitude of the taking camera at the moments of exposure. This procedure removes the lack of Y coordinate coincidence between the corresponding images of the two overlapping photographs. The lack of X coordinate coincidence is then due to relief displacement and provides a means of viewing and measuring the third dimension, or Z coordinate. The viewing of this anaglyph, printed in complementary colors, provides the observer essentially the same stereoscopic model that the Multiplex, Balplex or Kelsh instrument operator sees during the normal stereoscopic compilation procedure. Oriented absolutely to control, the geometry of the taking camera situation is recreated. It is our contention that when the projected images of this stereo model are photographed, the accuracy inherent in this orientation is "canned," awaiting only the proper techniques and tools to extract it.



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BACKGROUND

The discovery of the basic principles of the anaglyph is not new. In 1853, A. Rollmann wrote of his discovery of the principles involved in the construction of anaglyphic drawings. In his manual, published in 1932, O. von Gruber reported that Ervermann was probably the first to use photographic anaglyphs. He projected them on a screen in 1917. In 1934, G. Martin discussed the production of photographic anaglyphs and their application to the field of photogrammetry. The derivation of the mathematics of the constructed anaglyph was presented in 1941 by U. Graf. A. Cziszár, in 1942, published a paper which proposes the application of anaglyphic principles, to the rectification of aerial photographs by means of a very simple viewing and drawing device, for the purpose of map revision. In 1950, W. Brucklacher wrote on the use of anaglyphs to make stereo mosaics. Also in 1950, R. Burkhardt reported that the German Hansa organization started in 1942 to use anaglyphs for the purpose of illustrating stereo pictures and stereo mosaics. In 1952, S. Spurr wrote concerning the making of

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[1] Information contained herein does not necessarily represent the official views of the Corps of Engineers or the Department of the Army.

"Three-Dimensional Prints from Color Film." And finally, H. Kasper, in an undated Wild Heerbrugg brochure, has presented data concerning "The Production of Stereoscopic Pictures on Agfa Anaglyphic Paper."

Indeed, since the discovery of its basic principles, many attempts have been made to use the anaglyph as something more than an illustration tool. However, based on a search of available reference material, it is contended that this paper reports the first attempt: (1) to use stereo plotting instruments in obtaining the anaglyph, (2) to use the anaglyph for measurement purposes, and (3) to devise an instrument for this measurement.

Potential Applications

The potential applications envisioned for the photogrammetric anaglyph fall into three main categories: photo-interpretation, relief mapping and stereoscopic compilation of topographic maps.

In the area of photo-interpretation, it is contended that the photogrammetric anaglyph, together with instrumentation under consideration, will provide a useful tool. It will afford a three-dimensional map and the means to make precise measurements of this map. Preliminary testing indicates that the accuracy of these measurements approaches the accuracy of the plotting instrument which projected the stereo model. That is, with Multiplex, the estimated vertical accuracy of the determination of spot elevations would approximate $h/3{,}000$; with Kelsh, $h/5{,}000$. Moreover, the pictures will be perfectly rectified and oriented with respect to each other. Consequently, juggling of the pictures under the stereoscope will be eliminated. The base setting will be predetermined, thus providing the optimum scale for the analyst. When taking measurements, he would observe his measuring mark as would a binocular-type, instrument operator. However, for viewing only, the analyst's position may be as he determines to be most comfortable. It is estimated that group consultant viewing could accommodate at least four persons whereas consulting-type, scanning stereoscopes permit only two persons to view simultaneously. In addition, the photogrammetric anaglyph will require no adjustment for scanning purposes as does the stereoscope. For larger group briefings, these anaglyphs may be projected on a screen and viewed by large audiences with filter glasses.

It is believed that the photogrammetric anaglyph could be used as a relief map substitute when the publication scale approximates that of the model under projection in the stereo instrument. A model can be oriented and exposed in one to two hours. Therefore, it is believed that a stereomap of one or two stereo models could be made in less than a day. This provides, to anyone who can see stereoscopically, an absolutely oriented 3-dimensional picture. Being in reality, flat, this map would be more portable than a normal relief map. It is believed that it could be rolled, but that folding would cause distortion of the images. It may be determined feasible to print these anaglyphs on the back of large-scale maps to provide the user with both a 2 and a 3-dimensional product in one package.

Perhaps the greatest application, however, would be in the areas of photogrammetric stereo compilation. The compiler, using such an anaglyph, does not need to have model orientation ability; once set up and exposed, this model can never be disturbed by accident or vibration. It is, in effect, "canned" on film or paper. Therefore, an elaborate stereoscopic instrument is needed only for the model orientation and exposure. It is believed that compilation could be performed by a relatively cheap pantograph arrangement. Furthermore, in an emergency, when calendar time is of essence, several copies of a given model could be produced, thus making it possible for several operators to work on it simultaneously.

Investigation

The approach, to date, has been (1) to explore what has been done in the area, or related areas, by others, (2) to experiment with exposure and processing, and (3) to develop a device to read the Z coordinates of points on the anaglyph.

English literature, except for the paper by S. Spurr, mentions the anaglyph only as an illustration tool. A search of German literature, available in the AMS library and the Library of Congress, has yielded some half-dozen articles specifically on the subject of the photographic anaglyph. Although the translations have not been completed, scanning of these articles indicates that the anaglyph has as yet not been exposed under stereo projection nor has auxiliary measuring equipment been developed to put the anaglyph into the field of precision measurements.

The Army Map Service experimentation began, under the immediate direction of F. Bizzoco, with the absolute orientation of a stereo model, in an arbitrarily chosen Bausch and Lomb Multiplex instrument. See

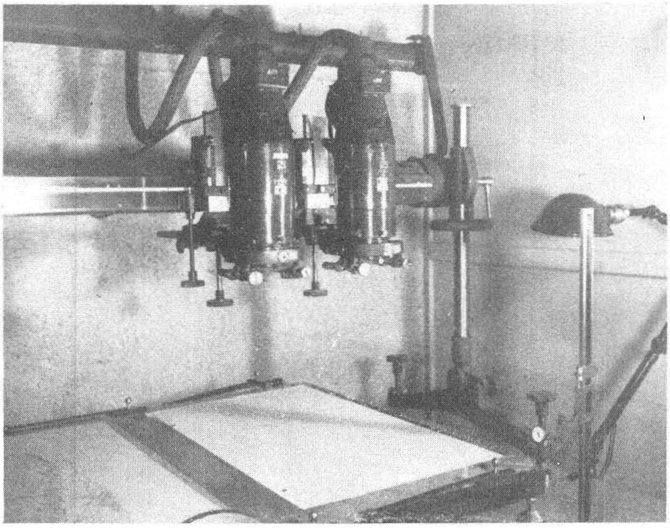

FIG. 1. Arrangement used to expose anaglyph.

Figure 1. The photography was taken with a 6″, KC-1 (Planigon lens) camera at an altitude of 20,000 feet over rolling terrain of Camp Roberts, California. The elevation of the terrain varied from approximately 540 to 1,240 feet. This model was oriented to geodetic control in the conventional manner. A platform, equipped with a vacuum back, was then placed under the oriented model at a projection distance of 340 mm. This projection distance was chosen so that the lowest point in the stereo-model would be above the exposure plane. Exposure was then made separately for each projector on orthochromatic topo-base film. The individual pieces of film were oriented properly by means of registration marks, photographed using a half-tone contact screen and printed by the rub-on process.

Although this proposed method does not currently provide an anaglyph as sharp as that which would be made by a rectifier, it is believed that this procedure inherently provides a more accurate rectification. The resolution of this anaglyph was visually determined to be as good as that of the basic Multiplex model itself. That is, apparently nothing, visible to the unaided eye, was lost in the exposure, processing and printing procedures. The accuracy, although presently weakened by separate exposure and later registration matching, will undoubtedly be strengthened by the use of a special two-color paper manufactured by Agfa. The plotting instrument projectors then will serve as absolutely oriented enlargers. This anaglyphic paper and corresponding chemicals are on the market and AMS has recently obtained samples.

The anaglyph, exposed, processed and printed in the aforementioned manner, was measured by a device developed for this purpose. See Figure 2. This device consists of a standard Multiplex-Balplex-Kelsh tracing table with the regular platen and the drawing pencil removed. A transparent platen, with a black dot engraved on the underside, replaces the normal platen. Filter viewing spectacles are mounted in a stereoscope-like attachment to the tracing table horseshoe. This instrument provided the means to take vertical measurements of the terrain to a repeatability equal to that of the original Multiplex model (± 0.1 mm.).

Just what do we have now, that we are trying to measure? See Figure 3. We all know that photographic scale is the ratio of the ob-

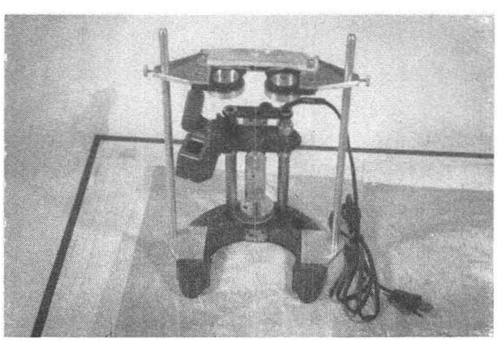

FIG. 2. Anaglyphometer—Device to measure anaglyphs vertically.

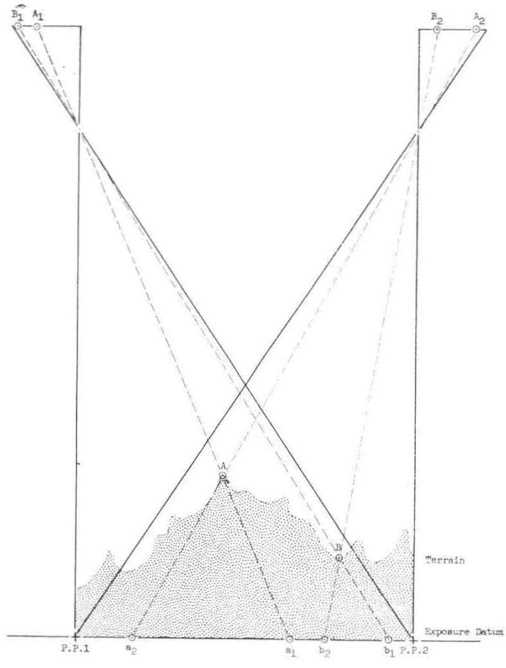

FIG. 3. Anaglyphic exposure of a stereo model.

ject distance to the image distance; that, over a plane, the scale of all points on a photograph is the same; also we know that over terrain of varied elevation, the object to image distances vary, and consequently the resulting scales of the various images on a photograph vary accordingly. In addition, we all know that the scale of the manuscript, under compilation, is the ratio of the instrument projection distance to the altitude of the aircraft, and that since the plotting procedure automatically provides a shortened projection distance where the altitude has been shortened due to relief, a continuous-scale compilation model results.

However, the photogrammetric anaglyph, as photographed at one plane, contains all the displacements due to relief, or in other words, scale is varied as a function of relief. So, this displacement property, which provides a means to view the anaglyph also presents problems when it comes to attempting to measure it precisely. Some of you probably know that as you view an anaglyph and move your head appreciably, image shifts appear. These do not destroy the stereo effect, but unless minimized, would render it impossible to measure the anaglyph precisely. This problem of image shifting is currently solved by attaching the filters as shown in Figure 2, and requiring that the operator use the head-rest provided. Vertical readings of the photogrammetric anaglyph, using the device described, contain, naturally, inherent geometric displacements as a function of relief. These displacements were removed during this investigation by straight-line graphical correction. The RMS error of the vertical values read off the anaglyph by the reading device, as compared with the 11 given geodetic points, was ± 8.3 feet or $h/2{,}450$. This compares with $h/3{,}000$, which is normally obtained with Multiplex equipment.

ACTION PLANNED

Efforts are presently being made to compensate automatically for the vertical errors inherent in this procedure of obtaining Z coordinate measurements. It is thought that a gear arrangement which would vary the viewing plane of the Anaglyphometer relative to the measuring plane, as a function of relief, would provide a solution. Vertical values, directly in feet or meters, could then be supplied the photo-interpreter as he reads his dial. Upon the solution to this problem, the investigation would then turn toward the solution of the horizontal displacements. See Figure 4. Should these horizontal displacements be effectively and economically solved, the next step would be the attachment of a simple pantograph to provide a stereo-compilation device which would permit the use of

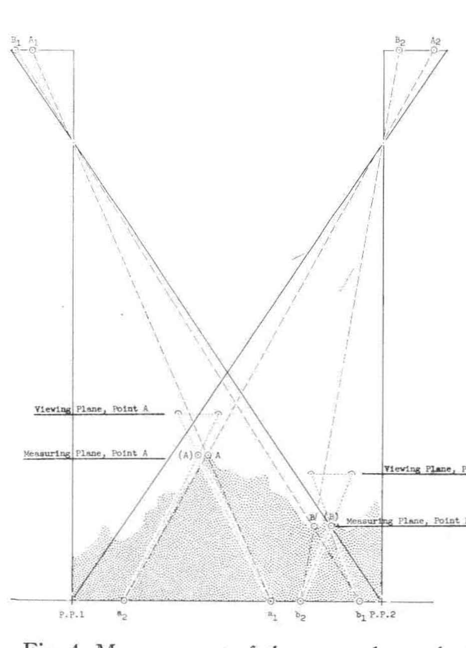

Fig. 4. Measurement of the exposed anaglyph.

semi-skilled personnel to produce stereo-compilation to a close approximation of the accuracy of the original instrument that projected the absolutely oriented model.

Consideration is also being given to the procurement of instrument projector lenses which have a minimum depth of focus, since this requirement, which exists in plotting equipment, is not applicable to the projection of the stereo model onto a plane. Freeing the lens designer of this restriction would enable him to concentrate on the attainment of other desirable lens characteristics, such as resolution and reduction of illumination fall-off.

Conclusion

These preliminary investigations indicate that the photogrammetric anaglyph in both resolution and vertical accuracy, approaches the instrument used to project the original stereo-model. It is believed then, that any increase of these qualities in the projecting instrument will also be reflected in the anaglyph.

In the process of exploring the potentials of the photogrammetric anaglyph, we have run into problems, and undoubtedly there will be many more which we do not even foresee at this time. It has been said that if only the problems of a certain situation are considered, no progress will ever be made. So exploration will be continued. A preliminary comparison of the anticipated problems against the potential advantages indicates the feasibility of the turtle sticking its neck out in order to move forward.

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*How Aerotriangulation Can Reduce Ground Control Costs**

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ABSTRACT: *The practical application of modern aerotriangulation methods by a professional user is discussed. The considerations of planning the project with available equipment, the accuracies involved, and a comparison of costs between methods is undertaken. An actual project is used to present the problems involved and the solutions obtained. The saving in time and money by use of carefully planned aerotriangulation is illustrated.*

AEROTRIANGULATION, or photogrammetric bridging, has been employed for a number of years to reduce ground surveying costs in connection with establishing ground control for high-order accuracy aerial mapping. Yet surprisingly little has ever been published on the subject from the viewpoint of the practicing professional user of the technique. Aspects such as project procedures, balancing the accuracy of photogrammetric equipment with the needs of the specific assignment, and, most important of all, *cost*, have hardly ever been discussed in public.

It is time that the mantle of secrecy, veil-

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