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INVESTIGATION OF VISUAL PERFORMANCE IN STEREO-PLOTTING USING VIDEO TECHNOLOGY.

(The three sections of this paper form a linked research project.)

ABSTRACT.

(a) A dual-observation system for the Topocart stereoplotter is discussed. The optical system is attached to a rigid top-plate to be used in place of the cover plate without interfering with the existing optics.

(b) An infra-red video system is used to monitor the dynamic visual behaviour of an operator's eyes while stereo-plotting, and to relate this to problems in contouring, particularly in the case of trainees.

(c) Where movement is involved, there are environmental hazards, poor conditions of visibility, or electrical transmission of scene detail is necessary, stereoscopic video has an advantage over conventional photographic photogrammetry. The author discusses, as a further extension of video technology from (b), the use of stereoscopic video for photogrammetry, and the quality of analysis and degree of accuracy possible using commercial equipment.

(a) A DUAL-OBSERVATION SYSTEM FOR THE TOPOCART.

When operators are being trained as stereo-plotters, it is a particular advantage if an experienced observer can view the stereo-model being seen by the operator while he is actually stero-plotting. Any mistakes that he is making, or difficulties he may be experiencing contouring, are then more readily apparent than when he has to stop, and his supervisor views the scene subsequently. Dual-observation is also a considerable advantage when discussing with a client the application of photogrammetry. Though a number of mirror-stereoscopes, and some more sophisticated photogrammetric interpretation instruments, have facilities for dual-observation, this facility is available on only a limited number of commercial stereo-plotters such as the Wild B8.

The author, in Bedwell (1971 & 1972), has been particularly concerned with the investigation of the more complex visual anomalies in relation to stereo-plotting performance, involving the initial selection of trainees, methods of monitoring their subsequent performance. A dual-observation system allows the observer to note aspects of a stereo-model which appear to be giving difficulty in maintaining accuracy of contouring, e.g. when the stereomodel is ill-defined, or accuracy is affected as the operator becomes fatigued. If deviations of accuracy, against known contours, can be recorded in synchronisation with any anomalies of visual dynamic behaviour, more meaningful data can be obtained.

The Topocart stereoplotter is widely used as a production instrument. The optical design of the viewing system is housed in an overhead T-shaped casting, with the viewing binoculars at the end of the T, and the two observational systems for viewing the travelling dia-positives on the end of the top of the T. The dual-observation system is mounted on a rigid T-shaped plate, of the same size as the T-shaped cover, and simply replaced instead of it. Prisms, forming a cube, are suspended from the top plate to act as image-splitters in each of the lightpaths, between the prisms directing rays to the eye-pieces, and the lenses prior to this stage. The rays from these cubes are then directed upwards to a prism reflector, where they are taken through lenses forming an objective lens system for the dual-observation binocular eye-pieces. In the Topocart the eye-pieces are attached to a precision metal plate, which also carrys the necessary prisms to receive rays from the lens system forming the objectives for the binocular eye-pieces. A similar eye-piece assembly is used for the observation system, and mounted at the same angle of inclination as the original eye-pieces.

In the original version of the dual-observation system, the dual observer eye-pieces are mounted on top of the T-section on the opposite side of the instrument. This results in a simplified form of construction adequate for the purpose required, and also makes possible the attachment of suitable video cameras to each eyepiece, with the cameras suitably supported, so that synchronised stereo video recordings and displays can be made of the stereoplotting process.

In a second version of this dual-observation system, the rays coming from the prismatic reflectors on the top of the plate assembly from the image-splitters below, are further reflected by two pairs of reflecting prisms, so that the dual-observation viewing system can be mounted at the side of the original viewing system. An L-shaped extension is then included coming from the side of the central Top-plate assembly to carry the necessary optical systems.

In both designs the dual-observation device can readily be transported and used with any Topocart instrument.

(b) THE INVESTIGATION OF VISUAL PERFORMANCE IN STEREO PLOTTING USING VIDEO TECHNOLOGY.

For many years the author has been interested, Bedwell (1971 & 1972) in the visual aspects of photogrammetry, and relating less recognised and more complex visual anomalies to stereoplotting performance. Stereoplotting involves dynamic binocular viewing of a stereo model, which is constantly being moved to permit following contours correctly. Visually it is a more difficult skill than is using a stereocomparator, where parallax co-ordinates are obtained from a series of sequential stereomodels viewed under more or less still, or static, viewing conditions compared to the dynamic viewing necessary in stereoplotting. Though considerable experience may be necessary for adequate analysis when viewing a stereomodel for photogrammetric interpretation, it is again a less exacting visual skill than contouring. For example, the author has found that some slow trainees have had a good stereoscopic acuity as assessed by the Dolman 3-rod test at infinity, where static viewing is involved, but can experience difficulties in maintaining accuracy under the dynamic viewing conditions involved in stereoplotting. In some cases more prolonged testing using the 3-rod test can result in visual fatigue producing a reduction of stereoscopic acuity. The 3-rod test, Moessner floating circle test, and other simulated stereoscopic tests cannot entirely predict suitability, or adequate performance later, for candidates for stereoplotting work. In consequence the author has been particularly concerned in attempting as much as possible to simulate real working conditions, and then developing objective methods of investigating, and analysing visual behaviour while undertaking these tasks. The data thus obtained can then be considered in relation to other necessary previous visual tests. In a number of areas involving visual ergonomics, e.g. visual display units, and also in reading difficulty, the author Bedwell (1978 & 1980), has found that though conventional visual static tests can indicate normality, investigations of dynamic visual behaviour and ocular control, while undertaking the task, show up anomalies of dynamic visual functioning which appear highly significant.

Observation of the eyes while viewing through eyepieces is difficult. The exit pupil of the eyepieces of most stereoplotters appears to be approximately 10 to 12 mm from the rear of the eye-piece lens. The use of an eyepiece and magnification necessitates a reduction of the field of view of the stereo-model seen, and if the distance from the eyepiece to the eye is increased, the field of view is decreased. As the luminance of the photographic stereomodel is limited, additional illumination of the eyes to make observation easier produces distraction of viewing. To permit actual observation of the eye while viewing through eyepieces the author utilised two infra-red video cameras, viewing via small dichroic mirrors placed at 45^{o} in front of each eye piece, and illuminating the eyes by low voltage infra-red light. By this means large images of the eyes could be observed on the video monitors, magnifying any variations of gaze exhibited by the stereoplotter. The video observation system was designed so that each eye would approximately fill half a standard video frame format, and recordings could be made on one video track.

Initially deviations in dynamic visual behaviour while contouring a stereo model have been assessed in grades by observers experienced in this work. To enable 2-dimensional quantification of movement to be obtained from the video scene, methods of analysing the video wave form to produce dimensional quantification are being developed by the author and his colleague, Mr R. Chapman, in the Electronics unit of the university.

So far experimental results indicate that as the stereomodel exhibits less contrast and texture, and difference in parallax, and consequently a reduced binocular fusional lock, greater difficulty is experienced in maintaining adequate directional binocular co-ordination, particularly with less experienced stereo-plotters, those with reduced binocular dynamic function, and as fatigue increases. As difficulties in binocular co-ordination increase, it is difficult for the operator to direct his eyes to where he wishes to look, resulting in images of the scene falling on slightly different retinal areas compared to the retinal areas that he would normally use in correspondence together. The ability to determine spatial location in each eye from established retinal correspondence is then disturbed, and binocular performance and spatial judgement tends to deteriorate. The less experienced the observer, and the less developed his binocular visual system for stereoplotting, the more likely he is to experience difficulties and reduction in visual performance, and hence contouring accuracy. Maintainance of adequate binocular alignment tends also to increase as the operator tracks dynamically over various areas of the stereo-model, particularly when he is working with poorer stereoscopic relief, and stronger stereoscopic detail become further away from the area that he is examining. As this research progresses, and the sophisticated quantative techniques being developed are employed, it is hoped to be able to record in synchronisation quantified variations in visual performance to deviations in contouring accuracy, from previously known accurate contouring data.

(c) <u>THE APPLICATION OF STEREOSCOPIC VIDEO TO PHOTOGRAMMETRY</u>.

Interest in utilising video technology for obtaining 2-dimensional quantification of movement, and general interest in photogrammetry, has resulted in the author being concerned with the further development of video technology to stereoscopic video, both for interpretation and analysis, and later for 3-dimensional quantification.

Where it is applicable, conventional photogrammetry, using metric photographic cameras, provides a relatively simple and accurate method of obtaining 3-dimensional data for land surveying, and for many close-range applications. Commercially though not necessarily militarily, because of it's application to map production, concentration has largely been on dimensional accuracy. In many applications, however, the facility of being able to view a scene stereoscopically, compared to a 2-dimensional view, greatly enchances the information that may be obtained regarding a scene, which otherwise might be very less meaningful. In conditions of poorer visibility, e.g. for military purposes, or for underwater survey, valuable interpretation can be made, which would not be possible with 2-dimensional viewing. For general interpretation the considerable advantage of stereoscopic viewing alone, as with stereoscopic video, may make non-metric cameras adequate for interpretation purposes.

Increasing interest is being shown in the application of photogrammetry for non-contact measurement close-range purposes in engineering, ergonomic studies of the body, and in human and vetinary medicine. Where the study of motion is involved, it is necessary to use either sequential flash photography, or light-trace techniques, both of which are limited in their application. Also where there are environmental hazards, poor conditions of visibility, immediate recall of a scene detail is necessary, or ready transmission electrically of the scene detail is needed, stereoscopic television systems have an advantage, though they are more complex, and calibration is more difficult.

In a video system the limitations of definition are determined by the vertical and horizontal line resolution, the definition of the scanning spot, the preciseness of scanning control, including correction of scanning geometry, and compensation for changes such as temperature. Because the scanning angle required for the video camera is considerably less than that involved in the video monitor, the achievement of precise control is somewhat more difficult to attain in the monitor than in the camera. For photogrammetric applications smaller monitors with flat screen face can be used though the demands on electronic geometric correction are greater, but with larger monitors a curved screen is necessary, making necessary additional photogrammetric correction. Though for a known model viewed by the camera, analysis of the video camera scanning wave form electronically is possible in general the camera and monitor have to be calibrated as one.

As an initial feasibility study of applying stereoscopic video to photogrammetry, not only for the purpose of 3-dimensional measurement but also for the advantages to be gained from viewing a scene stereoscopically, two standard inexpensive commercial video cameras incorporating ordinary industrial grade one inch diameter vidicon tubes were set up on a special stand with their optical axis parallel and separated by a base distance of 60 cm. The cameras were converted to take two 35 mm focal length wide angle Jupiter 35 mm camera lenses, with the model to be viewed placed at 2.5 metres. The lens consisted of a rectangular flat plate, from which projected a number of different length dowel pins, 0.5 inches in diameter, and set in a grid formation at four inches centres, an aluminium casting of a clutch housing and gear box for an automobile, and a dress-modelling dummy. The cameras were coupled to two standard nine inch diagonal video monitors mounted on a stand so that they could be viewed stereoscopically using a Hilger-Watts mirror stereoscope in place of the conventional dia-positives. Initially the cameras and monitors were set-up electrically with as similar geometry as possible. The monitors were then moved into the correct position by racks in the same way as would be the dia-positives, so that a stereo model of the scene could be viewed. With this simple set-up it was found that it was possible to differentiate height differences of 3 mm at 2.5 metres, or approximately 1 to 830, over the scene, without difficulty, and that the facility of stereoscopic viewing considerably enhanced the modelling and form of a display, in spite of the relatively low definition possible with such a system. The results were felt to be sufficiently encouraging to proceed to a more sophisticated system capable of better definition and accuracy.

In the next stage of this project two Jackson (Newark) precision cameras are being used, inconjunction with English Electric one inch diameter high, definition, vidicons for still scenes, or Leddicons tubes, with synchronised shutters exposing the tube during the interlace period, where movement was involved. To ensure compatability of the cameras, they were driven by a twin camera control unit, with careful attention being paid in the design to focusing and scanning geometry, automatic compensation for variables, a video processor to optomise picture quality, and electronic dynamic focusing to ensure correct focusing over the screen format, so that the best results could be obtained from a standard 625 line system. It is intended to convert a Zeiss Interpretoscope to take two 7 inch diagonal flat-faced Jackson precision video monitors, preferably with fibre-optic flat face plates, mounted underneath the viewing table, in place of the conventional dia-positives. By recording the video scenes from the two cameras onto two magnetic discs of an Eigen twin disc video recorder, still stereo models could be viewed, in sequence as desired, on the video monitors, for 3-dimensional assessment on the Zeiss Interpretoscope.
As an initial attempt to calibrate the system, a metric camera

is being used to photograph still models, so that dia-positives can be analysed conventionally on standard photogrammetric instruments.

The application of stereoscopic video to photogrammetry poses a number of difficult technical problems, but it is felt that the system could be a valuable adjunct to photogrammetry in situations were photography is not suitable, and that this work will widen the interest in photogrammetry and provide further basic data both as regards the development of the required technology, and the degree of quality of analysis that is likely to be obtainable with different types of equipment.

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