THE APPLICATION OF STEREO VIDEO PHOTOGRAMMETRY TO VISUAL AND RELATED ERGONOMICS.

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ABSTRACT.

Complex anomalies of dynamic binocular control, when the visual system is often conventionally assessed as normal, can result in associated anomalies of head and body posture, or can be caused by undesirable ergonomic stresses. From this situation can be produced stress and discomfort, both ocular and associated bodily related errors in visual and spatial judgement in everyday life, at work, and sport, and serious accidents can result. Of particular interest at the present time are man-machine interface situations, where visual demands may be greater and more extended than a classical work situation, and where problems of fatigue, stress, and discomfort, can result, together with a greater likelihood of errors, but where conventional approaches to investigation are technically inadequate to explain the causes of these problems. Professor Bedwell has been working for a number of years on a specially devised stereo video photogrammetric system where stereo video is used instead of photography to monitor, amongst other applications, anomalies of ocular control and body movement in real time.Analyse was by a Carl Zeiss Interpretoscope or by using a Carl Zeiss (Jena) Interpretoscope.

INTRODUCTION.

For many years Professor Bedwell, BEDWELL (1972 etc), FORD M.G. (1982), has been involved in the visual, binocular, and stereoscopic aspects of photogrammetry, and inconnsequence has become very interested in the usefulness of the technique and the number of applications it could have to non-contact 3 dimensional analysis and measurement. A great advantage of photogrammetry is that the investigator can analyse the visual scene in a similar format to which he could view it in real life, and thereby be able to readily make use of the expertise that he has already developed. The facility with a video-based system being able to display the stereo model in slow motion or sequential stills, makes analysis much easier than in real time. In studies of body ergonomics, and in clinical work in general, the investigator is often limited in being only able to give a subjective account of thesignificance of what he sees. Photogrammetry has the advantage of being able to provide non-contact 3-dimensional measurement permitting quantification clinically. Also ready comparison of stages during an investigation is possible as is comparison at different stages in time, and being able to communicate and substaniate with others the significance of the factors being investigated.

ANOMALIES OF VISION, OCULAR CONTROL,AND THEIR SIGNIFICANCE.

Over the years the author has found that there are many who suffer from visual difficulties, ocular discomfort and stress, amd associated neck and postural tension, that can result in difficulty in performance, spatial mis-judgement and educational under-achievement. The problems are more likely to arise and not be contained within normal physiological limits if the subject is asked to undertake tasks for which he is not visually and generally adapted, or ergonomic design is not as adequate as it might be and is producing undesirable stress. The symptoms resulting from these situations can often wrongly be diagnosed as being of psycho-somatic origin, and yet involve quite complex physical and physiological considerations going beyond the confines of many classical concepts. A new approach is often required in observation, investigation and management, which if undertaken successfully, can result in considerable benefit for the individual concerned,often appreciable improvement in performance, and sometimes the avoidance of serious accidents. Modern technology has introduced many new methods of working involving different methods of display, viewing, and manual operation, compared to long established traditional methods of working. Any anomalies of function which might affect reading, writing, and typing, may just be contained within normal physiological limits of the individual concerned, provided undue stress is not involved, but when the task is extended and there are,for example, increased demands for viewing over a greater range of positions and distances, problems of a complex nature may result because the person concerned may then be stressed beyond individual physiological limits. In a co-operative study LIE & WATTEN (1985) found that when the visual system was artifically stressed there was a significant increase in electrical potential in a range of muscle systems from the head downwards, indicating the widespread nature of stress.

We are born with the neural and physical potential of being able to undertake a considerable range of functions and tasks, e.g. binocular vision, but in general environmental adaptation is required to undertake these efficiently and comfortably, the time involved being determined by different charcateristics in the individual. For example, many factors are involved in determining the causes of educational underachievement, but Professor Bedwell has found that over a period of years complex problems of dynamic co-ordination on convergence can be of considerable significance in scanning while attempting to read, though when the child is assessed by simple static tests of visual acuity and extra-ocular muscle imbalance, conventional normality can be indicated. In other cases general bodily co-ordination, for example, in swimming may be quite good, but there has been a history of being accident prone and the child told that he is just clumsy, whereas in fact his problems may really originate from complex difficulties in dynamic binocular co-ordination affecting his visual spatial judgement. Another illustration would be someone who is able to type without difficulty, but when asked to operate a word-processing system using a terminal keyboard viewing a visual display unit experiences difficulty and discomfort. The reasons may not be exaplained adequately by a conventional visual examination. Taking a more sophisticated approach one possibility might be that on viewing the VDU the eyes may be required in fact to operate in a co-ordinated manner on convergence outside the normal range of comfortable binocular viewing for that individual.

In investigating patients who are likely to have problems it is necessary to set aside some of the classical concepts in which one has been trained, and to learn to look objectively at the patient and to be aware of anomalies which previously one might not have noticed. One must then adopt a logical reasoning approach saying that a possible range of difficult situations may be occurring and which set of conditions is more likely in an individual case. For example, much information can be obtained by being sensitive to anomalies of head position and general posture which may never have been noticed before. In developing ones clinical expertise and in being able to undertake comparative studies Professor Bedwell has found that over the years that two-dimensional and stereo video recording have been extremely valuable as it enables one to study the actual scene as it would be portrayed clinically, but with the advantage of being able to observe in slow motion, or as sequential stills, when often the actions in real time are too quick to enable adequate analysis. There is still however a difficulty with two-dimensional video as the interpretation has to be largely subjective,and it is a great disadvantage not being able to make adequate records. Through long interest in photographic photogrammetry, Professor Bedwell then became involved in the application of stereoscopic video,and this opened up the possibility of being able to employ 3-dimensional non-contact stereo video photogrammetry, allowing measurements to be undertaken in a way which would have been impossible otherwise. Being involved also in a wide range of technological work it seemed also that this was a technique which could well be employed to study other areas of body function, be employed for remote under-water viewing where stereoscopic binocular integration of the two images appreciably improves visibility and analysis under conditions of poor visibility,and then for example situations such as robotics where the facility of being able to study and measure in 3-dimensions actions that are occurring at high speed would be a considerable advantage. As a result successive stages of electronic stereo video photogrammetry have and are being developed to cater for requirements where photographic photogrammetry, which is complimentary, may have limitations.

TYPICAL ILLUSTRATIONS.

The following illustrations show cases where the facility of being able to record in stereo and later quantify could be a considerable advantage as the anomalies are of a complex nature when a simple approach would indicate normality. In the early stages,when stereo video is largely used to aid analysis,measurements on the stereo model were undertaken by placing a mark at the root of the nose just above the upper lip, and recording essential facial measurements, such as the distance between the centre of the eyes when looking in a certain direction. In these cases absolute calibrated measurements were not possible,but clinically it is often the relative differences over the range of the stereo models that is important. Subsequently different approaches to pre- and on-going calibration were utilised. The following illustrations were taken from 2nd generation video copies from inexpensive security video cameras and not a true indication of the definition that could be obtained with video.

For Mono view this side

For Stereo use split frame viewer.

FIG 1. This boy had a slight head tilt to the right from birth. He had a history of reading being difficult. Further investigation indicated great difficulty in ocular scanning control, which was associated with his anomalous head posture.

For mono view this side

For stereo use split frame viewer.

FIG 2a and FIG 2b. Mrs M. had had a long history of visual discomfort,and associated neck tension and postural stress, and in particular found reading for any length of time uncomfortable. Her problems had never before been satisfactorily explained but a dynamic binocular study revealed the causes. Though by conventional static tests she was nominally normal, under dynamic viewing conditions she was having to make a considerable effort to overcome a tendency for binocular divergence, resulting in the development of spasm or stress in the extraocular muscle system, related to neck tension, and postural stress. She was only able to move her eyes over a small lateral field of view before she experienced discomfort, blurring, and image break-up.

For mono view this side

For stereo use split frame viewer.

A B

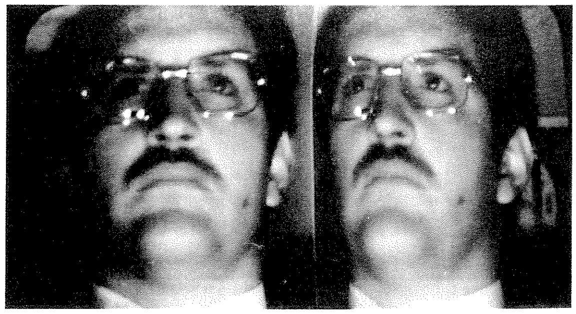


FIG 3. Mr.R. was is difficulties because of a series of minor car accidents, particularly on reversing, and when illumination was poor reducing visual contrast. He was slightly myopic in the left eye and more so in the right eye,though his visual acuity with a correction was normal, and conventional subjective tests of static binocular function indicated normality. On questioning he experienced little discomfort but did notice postural fatigue after much driving, had some difficulty when judging parking the car, and could mis-interpret a hand of cards when playing bridge. When investigated dynamically stereo video demonstrated on looking to the right he tended to over-converge the left eye, and diverge the right eye, but on looking to the left diverge both eyes. His vision then tended to become slightly confused, and his spatial judgement became poorer, hence the history of car accidents.

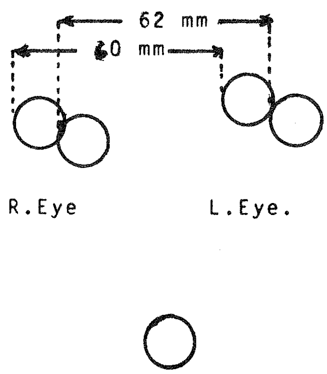


FIG 4. This diagram demonstrates difficulties in binocular eye control by recording the actual pupil positions while viewing with head fixed, a target moving slowly over a span of 60 cm viewed at a distance of 600 cm.

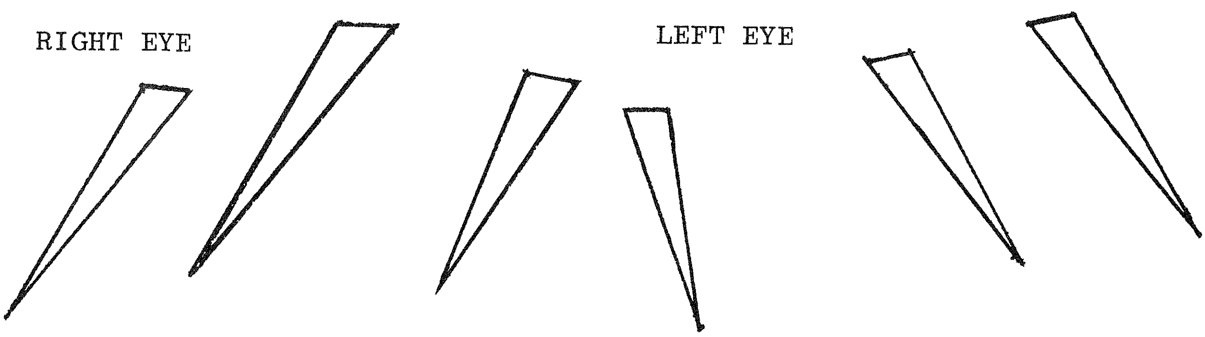


FIG 5. The next illustration depicts relative angle of divergence or convergence of the eyes in relation to the base of the nose while viewing a distant target moving the head slowly to the right and subsequently to the left. An appreciable lack of symmetry can be observed in the degree that the right eye diverges on rotation compared to the left eye. In this case there was a history of visual discomfort, and visual difficulty, including problems of spatial judgement.

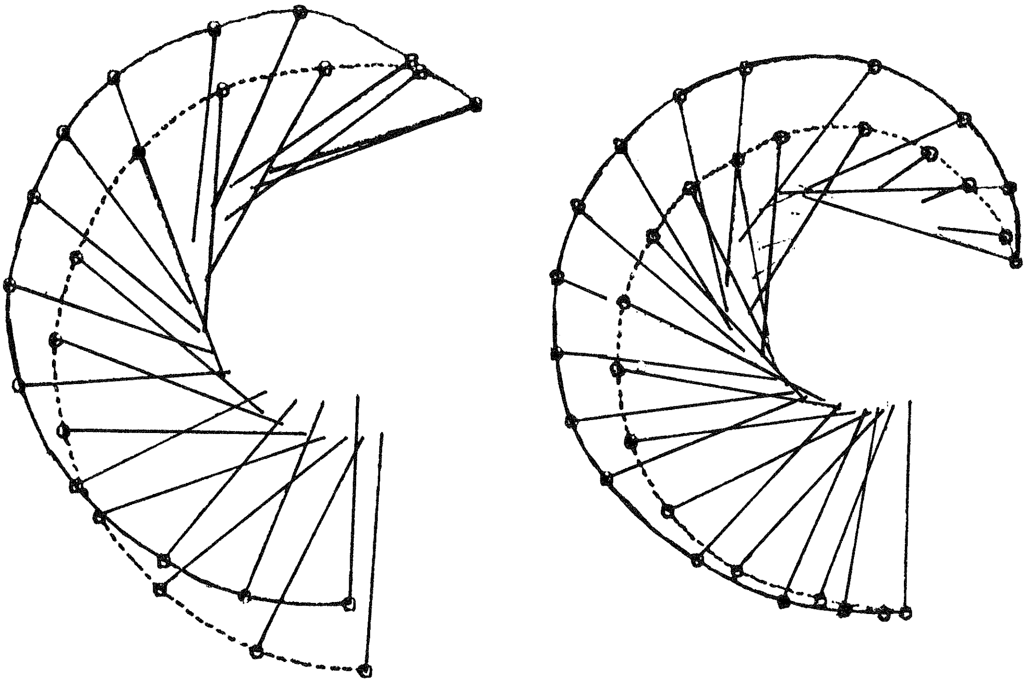


FIG 6. This illustration shows how stereo video photogrammetry, with surrounding controls, can be employed to study behaviour during a golf swing of a semi-professional player compared to a learner. It is later intended to add a dynamic visual study of players while taking the swing as it is felt that difficulties in visual spatial judgement could be a significant factor. The first illustration shows the analysis of a club swing of the semi-professional, and the second illustration the learner tending to lift off the club at the last minute of swing.

Although this is not a bio-mechanical study, work has also been undertaken on employing stereo video photogrammetry for analysis and measurement under-water with a view to employing the system for monitoring underwater robotic operations. Here a measured and marked steel framework was immersed in the water and used initially for calibration.

PHOTOGRAMMETRIC MEASUREMENT USING A VIDEO SYSTEM.

Conventionally photogrammetric measurement on a stereo model is made from high quality photographs taken with a calibrated metric camera. When a non-metric camera is used measurement of the stereo photograph is more difficult, as the camera is not likely to be built to the same precision. Also there is not the same provision for film flattening, or providing the usual fiducial marks from the camera on to the film. The nodal, and principle points of the lens system will not be accurately known. Errors can occur in the lens mount, and with lens adjustment, and also the distortion characteristics of the lens are unlikely to be known. It is therefore necessary to use a special mathematical approach to calculate the required equivalent geometry of the system. Instead of a photographic film, electronic image sensors are used with either electronic video tubes, or solid state devices with a pixel format. It is necessary also to allow for errors and variations that can occur with electronic image snesing. In addition the image has to be reproduced electronically on a cathrode ray tube(s), where again variations and inaccuracies can occur.

For many years Professor Bedwell has been using 2-dimensional video. and later stereo video, for recording anomalous ergonomic and bio-mechanical situations in clinical practice, particularly where movement is involved. In particular this has concerned complex anomalies of dynamic binocular eye control, related anomalies of head and general posture, and their relationship to ocular, neck, and downwards associated muscle stress situations. Initially mono and stereo video recordings were being observed in real time, under slow motion, and sequential stills, to permit better analysis of the physical changes that were occurring. The desirable quantification of these changes has naturally posed problems. As initially calibartion controls were not incoporated in the system Dr Bahani analysed them on the modified Interpretoscope by taking the base of the nose, just about the centre of the upper lip, as the reference point and incoporating some predetermined facial measurements such as the separation between the cnetre of the pupils at a certain position of gaze this limitation was not of such practical importance as might have been initially thought as in this application clinically what was important was the relative difference in measurement between sequential stereo models rather than absolute measurement.

For absolute measurements, in particular when employing stereo video photogrammetry it is necessary to use on-going calibration. A suitable system has now been developed for later recordings using calibrated models for these investigations of anomalies of ocular control and posture,as discussed earlier in this paper. Likewise in biomechanical studies of body movement and sport a surrounding frame of control points was used.

As also discussed earlier the Interpretoscope, to which were fitted digital encoders, was initially calibrated on known plates and models. Using then optically generating light marks the interpretoscope was found to be accurate within 10 microns, Distortions on the stereo monitors were determined by two approaches. Initially the first was to feed into the monitor an electronically generated known grid pattern, amd later a flexible range of computer generated stereo models of known dimensions, SHAH (1986).

EQUIVALENT GEOMETRY.

To determine the equivalent geometry of the uncalibrated stereo video cameras Dr Mahani used an approach used for calibrating non-metric optical cameras, in which photographs could be analysed in such a way as to permit the reconstruction of the bundles of rays along which the object was projected on the negative. As no fiducial marks are incorporated in the system, it was decided to apply a similar equivalent geometry as when the pictures would have been taken with a non-metric camera. The basic transformation equation which maps points of object space or to points in the image plane can be represented by :-

$$\begin{matrix} X + \Delta x - xp \\ Y + \Delta y - yp \\ -f \end{matrix} = K \begin{matrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{matrix} \begin{matrix} X - Xc \\ Y - Yc \\ Z - Zc \end{matrix}$$

where :

(X,Y) are the measured image co-ordinates of points (X,Y,Z,)
f is principal distance.

K is a scale factor

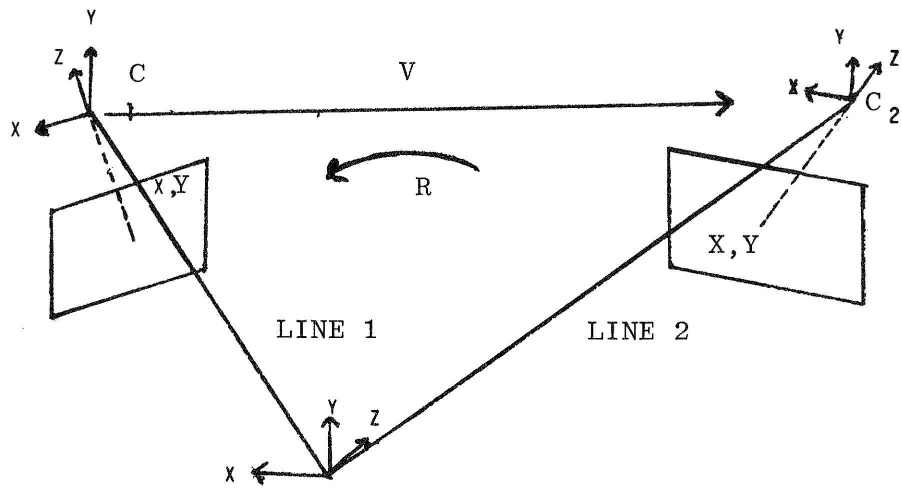
R is a parameter in the rotation matrix

N_p Y_p are the co-ordinates of the principal point.

Δ_X Δ_Y is the total distortion correction.

Xc Yc Zc are the spatial co-ordinates of the exposure station.

Thus given a number of reference points, the distortion parameters, principal distance+the principal point can be calculated. After calibration, the co-ordinates of a point can be calculated from the corresponding stereo points by the intersection of the two rays shown in FIG 7.



EVALUATION OF ACCURACY.

When adequate control points were available accuracy of the system could be obtained by comparing the results with the object space co-ordinates of a given number pf control points/ The assessment of the accuracy of the measurements is based on the root mean square of the spatial residuals. One control field employed wasa rigid frame primarily made as a reference for measurement of a golf swing. It consisted of 29 targets whose co-ordinates were accurately measured using two theodolites. The average rms for 6 tests were found to be 0.17 mm., 0.11 mm and 0.19 mm. in X,Y and Z respectively relatively over the model.

THE STEREO VIDEO PHOTOGRAMMETRIC SYSTEM.

The system employed at the Photogrammetric Research Centre was based around a Carl Zeiss (jena) Interpretoscope with the kind co-operation of Carl Zeiss. It was originally designed for precision analysis with dual observation optics a turret lens system with independent zoom,provision for internal correction for orientation, X & Y and px and py lead screw adjustment, and a stereo plotting mark. By fitting linear and rotary encoders it was possible to obtain 3 co-ordinate data which was fed to a computer via a Ross interface. When it was calibrated against known stereo photography it was accurate within 10 microns - more than adequate for many close range applications at a cost much less than a standard photogrammetric instrument It was possible to remove the light box and replace this by a mount containing two Jackson (Newark) good definition monitors. Two Jackson high definition cameras were mounted on a fully adjustable stand and the camera output fed to a control unit. The recording was by two Eigern (Prostab) video disc recorders capable of operating in realtime, variable slow moiton, or in freeze frame. The monitors were calibrated using a grid pattern generated in the camera unit or by a specially designed computer programme producing pure stereo models SHAH (1986). The video cameras were calibrated against known modules photographed by two Carl Zeiss (Jena) metric precision cameras. A relative accuracy over the stereo video model of 1 : 1000 was found to be achievable. In later systems with improved electronics and image sensors this accuracy should be improved. The present system is shown below. FIG 7.

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