Commission No. V Working Group No. 6

Authors: L.F.H.Beard MA, FIIP, FRPS Director
J.E.Tee MIS

Department: Medical Photography and Illustration Service

Address: Addenbrooke's Hospital, Cambridge, CB2 2QQ, England

Title: An Approach to the Introduction of Stereophotogrammetry as an Alternative to Traditional Methods of Measurement

Abstract:

A stereopair of photographs contains comprehensive and accurate information on the size and shape of the subject recorded. However, delay occurs in gaining access to this information due to the procedures involved in reorientation of the stereopairs in the plotting equipment. This, together with the skill required for taking measurements from a spatial model, has hindered the replacement of traditional methods of measurement by stereophotogrammetry.

Having designed a stereometric camera/plotter for clinical photography based on non-metric cameras and lenses, problems of reorientation have been minimised and methods of simplifying analysis have been devised. Our investigations and their applications to date are described and demonstrated.

It is now fourteen years since I commenced using stereophotogrammetry for recording children's faces as they grew and developed year by year from infancy to advanced adolescence. This study, which was undertaken for Professor P.H.Burke of the University of Sheffield, has been the subject of many papers and has provided information for his research which could not have been obtained by any other method.[1][2][3] In 1967 I reported on the development of a stereometric camera which was built in the instrument workshops of my hospital.[4] It was essential to do this since no commercially available short base stereometric equipment was suitable for our requirements.

Since then, I have improved on the design of my cameras, particularly with regard to portability, so that patients can now be photographed in stereo anywhere in the hospital with the same ease as when using 35mm cameras for making colour diapositives. As a result, much clinical research has come to rely on stereophotogrammetry to provide comprehensive documentation and measurement of pathological changes as described in the following examples.

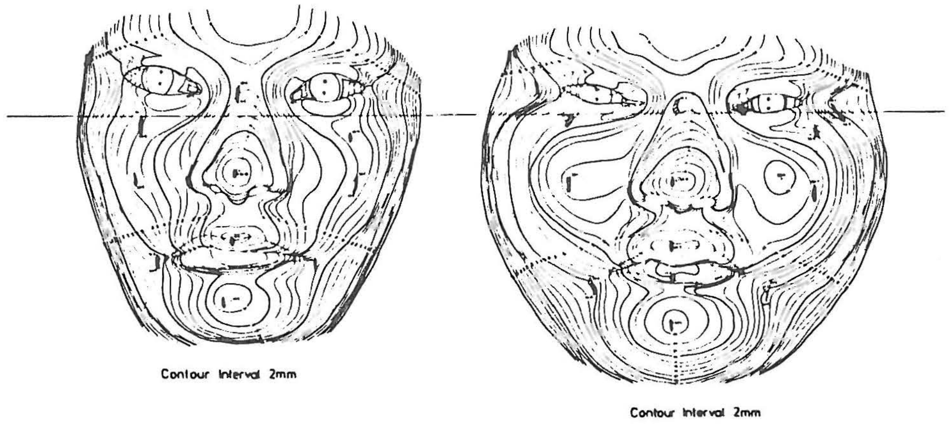


Figure 1 Pre and post operative facial plots of patient suffering from chronic renal failure showing changes due to immunosuppresive therapy.

A clinical condition arises from the changes in renal transplant patients receiving immunosuppresive therapy. The volume of the face together with the areas of selected cross sections are compared with similar oedematous conditions due to endocrine disease. (Figure 1)

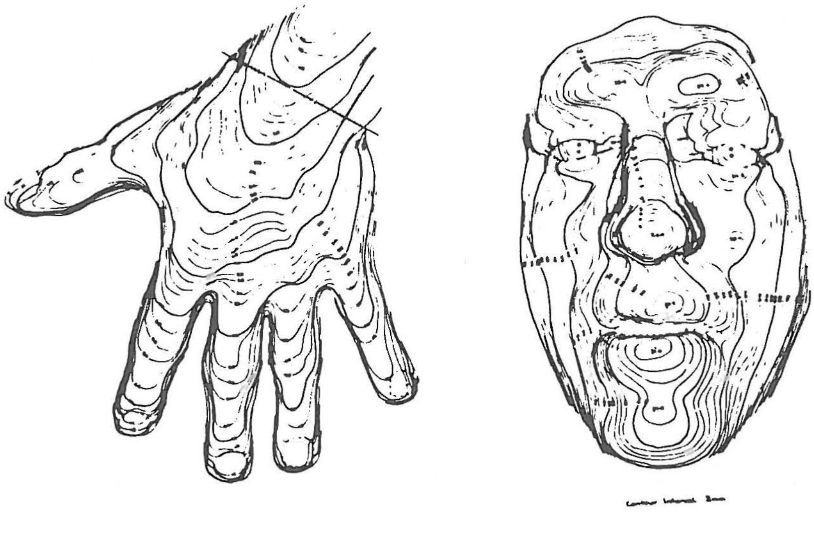
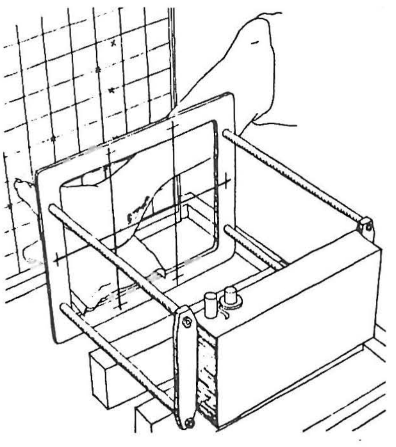


Figure 2 Plots prepared for volumetric studies of patients undergoing treatment for acromegaly.

Control of acromegaly by chemotherapy was confirmed in five patients receiving treatment and claims that the condition could actually be reversed were substantiated. (Figure 2)

A new dressing used in the treatment of varicose ulcers was compared with that currently in use and to this end only patients with bilateral ulcers were chosen. The new dressing was applied to one ulcer while the established treatment was continued with the other. Information was sought on the total area of each lesion together with the depth of erosion. Colour film was chosen since it was necessary to differentiate clearly



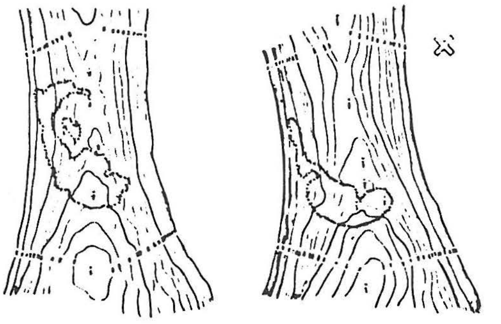


Figure 3 Photography of varicose ulcer. Area defined by dotted line shows reduction in size over 3 months but increase in volume of leg due to DVT. Contour interval 2mm.

between necrosis and healing and photographs were taken at monthly intervals. Standard colour slides were also taken for simple visual assessment on each occasion and these alone provided valuable information on the stages of healing. Certain clear patterns emerged which may have a long term influence on the treatment of this condition but a salutary lesson was to given to those who doubted the validity of stereophotogrammetry. Ulcers showing significant changes were chosen for detailed analysis. The plots shown in Figure 3 revealed the anticipated change in shape and diminution of the lesion but the volume of the leg had increased. The accuracy of the measurements was at first questioned but, on further examination, the patient was found to have developed a deep vein thrombosis. Subsequent studies confirmed the continued regression of the ulcer with the leg having reverted to its normal size. It is unforeseen episodes such as this that give biostereometrics the recognition it merits.

It is, therefore, somewhat surprising, not to say disappointing, to find that stereophotogrammetry has not, as yet, replaced the conventional approach to routine clinical measurement. A recent survey into this showed considerable lack of precision in some of the instruments in use and in the methods employed in using them. These included string, tape measure, ruler, calipers, goniometer, exophthalmometer, contour frame or just estimates by eye recorded by memory. The general impression was of a rather casual approach to the whole subject. This was highlighted by the fact that we were repeatedly assured that the accuracy which we claimed for stereophotogrammetry was not relevant to the needs of the clinician.

We, therefore, decided to examine the criticisms and shortcomings of stereophotogrammetry as compared with other measuring instruments and to overcome these as far as possible. We should then be able to highlight its advantages with a view to surmounting the inevitable prejudice with which the medical profession greets any innovation.

The following disciplines, active in the field of measurement, were chosen for this approach:

Dermatology, Endocrinology, Geriatrics, Ophthalmology, Orthodontics, Orthopaedics, Paediatrics and Respiratory Physiology.

The advantages of stereophotogrammetry are listed as follows:

i) the recording of the stereopair of photographs puts the patient to no more inconvenience than routine clinical photography;

ii) there is no physical contact with the patient therefore there is no risk of hurting or infecting the patient in any way;

iii) soft tissue areas are not distorted and inaccessible regions, such as the eye or internal anatomy exposed during surgery, are as readily recorded as surface detail;

iv) the results are available for simple visual assessment and comparison with serial records thus providing valuable permanent documentation;

v) the stereopairs yield measurements to an accuracy of 0.5mm and the information may be provided in the form of contour maps, volumes, surface areas, cross sections or simple measurements from point to point.

In order to substantiate our claim to be able to provide all these facilities, we had first to reduce the cost of our cameras and then to eliminate the need for sending our stereopairs away, except for detailed analysis and plotting, since this introduced an unacceptable delay and was a service for which we would have to pay.

Professor Karara, in his keynote address to the symposium on Biostereometrics held in Washington in 1974, made reference to the use of non-metric cameras in close range stereophotogrammetry.[5] His findings showed that the accuracies obtained were completely acceptable in the biomedical fields. Thus encouraged, we have now designed a stereometric camera using standard 35mm cameras which require no modification other than the fitting of glass stage plates in the focal plane to ensure film flatness. For our work, lenses with a focal length of 28mm are used. The cameras are rigidly mounted on a metal frame having a base length of 140mm and height of 350mm. Wires, intersecting at the principal points, are attached to the frame for reorientation purposes.

Analysis of the stereopairs, which take the form of 35mm diapositives in colour, is carried out by projecting these through the cameras. Lamp houses were specially designed and constructed to replace the camera backs, the film being held in contact with the stage plates by spring loaded optical flats. A point source of light is focused through a simple condenser system so that the image of the filament lies in the optical centre of the lens and comes to a focus in the plane of the diaphragm, fulfilling the same conditions as in Multiplex plotters. The camera fits on to a plotting table thus forming an integrated unit. This consists of a horizontal screen which may be raised and lowered, its height, corresponding to the z co-ordinate, being read in digital form from a LED display or entered directly into a microcomputer. Similarly, the x and y co-ordinates of any spot height may be recorded on graph paper together with the z co-ordinate or the graph paper may be replaced by a digitising tablet to provide the appropriate data input for the computer so that any desired display or calculation may be acquired quickly and accurately.

Initially, the data from our stereopairs were derived from maps made at a contour interval of 2mm. However, experience has shown that the distances between predetermined points, which may be anatomical landmarks or marks made on the skin, were in many cases all that were required. Where profiles were needed to reveal changes in the subject due to growth or disease, these have been derived simply by recording only the co-ordinates which lay along the relevant section of the stereomodel.

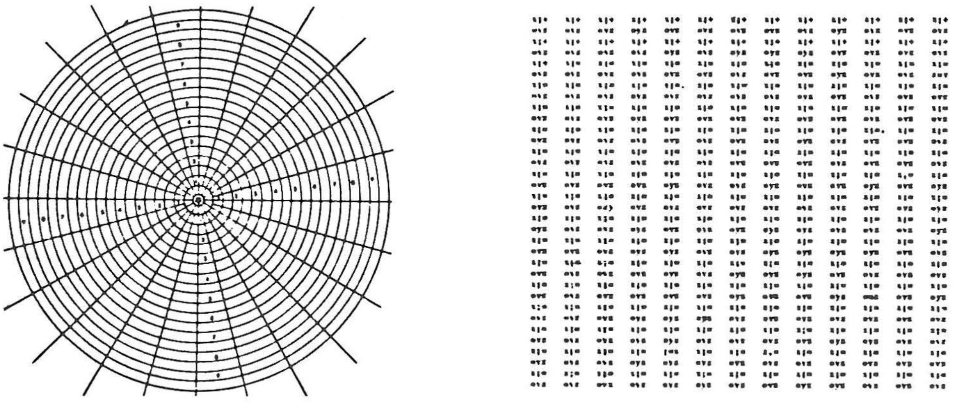


Figure 4 Examples of patterns projected to produce reference points

In order to remove complete dependancy on the ability to observe a three dimensional image, we have sought means of introducing clearly visible reference points on the subject in the absence of suitable anatomical landmarks or skin impurities. The most successful of these has proved to be the projection of points on to the surface of the skin through the primary light source. Points in a random pattern were difficult to identify with confidence and so we designed arrays for specific purposes. (Figure 4)

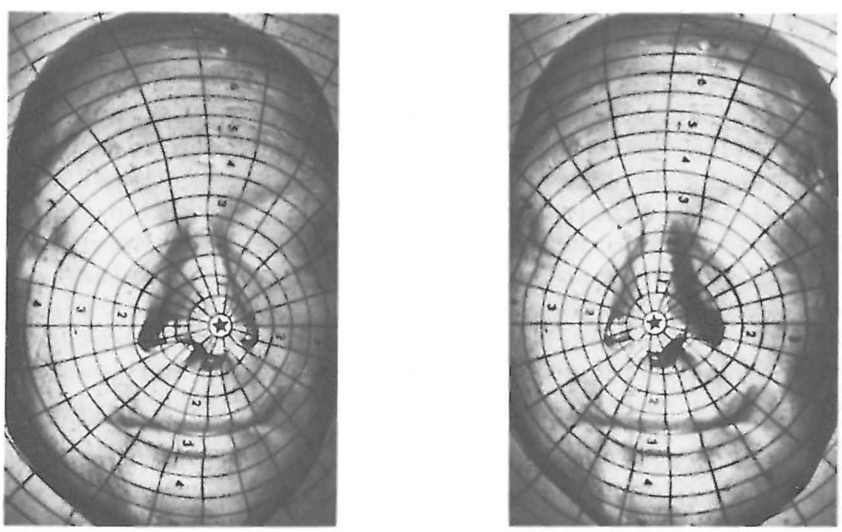


Figure 5 The effect of projecting lines radiating from the perspective centre of the projection lens

Lines radiating from one point, if arranged so that their origin is from the perspective centre of the projection lens, may be deemed to be devoid of lateral displacement and undistorted by variations in magnification due to the depth of the subject. Thus, the deviation along any line, to be seen in the diapositives from left and right cameras, is due solely to the variation in contour of the subject.(Figure 5) When these lines are brought into coincidence on projection, the points where they merge lie along a single axis and a continuous string of co-ordinates may be recorded. The measurements which it is possible to make from stereopairs enhanced in this way range from the x,y,z co-ordinates of spot heights, through linear distances between two points and profiles along a specified axis to surface areas and volumes.

We thus have four distinct means of obtaining measurements depending on the complexity of the results required.

i) The co-ordinates of clearly defined anatomical landmarks or skin impurities can be measured directly from the stereopair, yielding spot heights and linear distances;

ii) in the absence of points of reference, marks may be made on the skin, the patient being requested to renew these if serial measurements are to be made;

iii) when profiling is also required, a radial grid pattern is projected on to the subject, this pattern being capable of yielding estimates of surface area and volume as well;

iv) it is only when extremely detailed information on the subject is required that it is necessary to plot the image stereoscopically in order to produce contour maps.

It has been possible to design a camera with plotting facilities which is relatively inexpensive while yielding results of sufficient accuracy to assess the progress of the disease under investigation. Measurements can be made rapidly without the aid of a skilled technician. However, should more detailed information be required, corrected diapositives, produced by projection through the camera lenses, may be used in standard plotting equipment for producing contour maps. We are not questioning the undoubted excellence of pure stereophotogrammetry but merely simplifying the procedures and speeding up analysis when limited information is required.

Digitising the output from the camera and linking this to a microcomputer greatly facilitates the analysis of the data. It removes the restriction on the number of co-ordinates to be read and ensures an uninterrupted observation of the stereomodel during analysis, allowing a rapid compilation of areas and volumes. The plotting of profiles can be carried out instantaneously, viewed on a visual display unit and, if needed, printed out as hard copy.

While recording the subject of interest, the surrounding area is also photographed. Thus, if changes there become significant, these too can be measured.

Finally, I would like to say that there is little doubt that, when the convenience and validity of stereophotogrammetry are no longer in question, the accuracy, so often rejected, will come to be appreciated when it is realised that for the first time minute changes can be observed. In this way, it may be compared with high speed and time lapse photography which have enabled events which occur too rapidly or too slowly for the eye to perceive to be observed in detail.

References:

1 Burke, P.H. and Beard, L.F.H., Stereophotogrammetry of the Face, Amer. Jour. Orthodontics, Vol. 53, No. 10, pp 769-782. 1967

2 Burke, P.H., Beard, L.F.H. and Tee, J.E., Biostereometric Analysis of Serial Growth Changes of the Lips, Applications of Human Biostereometrics, Paris 1978

3 Burke, P.H., Growth of the Soft Tissues of the Middle Third of the Face between 9 and 16 Years, Eur. Jour. Orthodontics, Vol. 1, pp 1-13. 1979

4 Beard, L.F.H., Three-Dimensional Contour Mapping by Photography, Phot. Jour., Vol. 107, No. 10, pp 315-323. 1967

5 Karara, H.M., Photogrammetric Systems for Biomedical Applications, Biostereometrics '74, pp 1-26.