MEASUREMENT OF SPINAL DEFORMITIES USING STEREOPHOTOGRAMMETRY

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ABSTRACT: Idiopathic scoliosis is primarily a cosmetic deformity comprising a scoliosis (lateral bend) and a rib hump posteriorly related to twisting of the spine as well as disordered rib growth. The authors were involved in a project looking at the use of surface shape for the assessment and monitoring of scoliosis. The aims of the project were to measure back shape and to show the reproducibility of the measurement. This paper describes the photogrammetric acquisition, restitution and measurement aspects of the project and outlines the results obtained and current directions being followed.

1. INTRODUCTION

1.1 Background

Idiopathic scoliosis is primarily a cosmetic deformity comprising a scoliosis (lateral bend) and a rib hump posteriorly related to twisting of the spine as well as disordered rib growth. It typically occurs in pubescent girls and may progress during adolescent growth phase or early afterwards. Only in severe deformities does it interfere with respiratory and cardiac function.

The management of idiopathic scoliosis is twofold. Firstly, to identify those curves which are progressive, and secondly to surgically recreate the optimal cosmetic trunk appearance and prevent further progression in those patients whose deformity exceeds acceptable limits.

Identification of the condition is largely through school health screening programmes and is based on a crude assessment of rib hump. Further assessment and monitoring are both clinical (using instruments such as spirit level) and radiological (using X-rays to measure the lateral deviation of the spine). However, the radiographic parameters do not necessarily correlate with actual rib deformity and correction of the scoliosis by surgery may not correct rib hump.

Monitoring the condition is both clinical and radiological and continues until after skeletal maturity. However, multiple radiographic examinations in this age group of girls is not considered desirable. While not the only method available, photogrammetry is a non contact, non invasive method of measuring the three dimensional back shape of patients and offers the possibility of reducing or minimising radiographic examinations.

1.2 Experimental Procedure

A series of stereoscopic photographs were taken of a group of twelve patients. This series consisted of an initial set of three photographs at a single sitting where the patient was photographed in a frame, then removed from the frame for a period of time, repositioned and rephotographed. Each set of photographs was followed by the radiographic examination normally used in the clinic to allow later comparison of back topography with X-ray parameters. This initial set of stereophotographs was used to determine the reproducibility of the technique. Subsequent series of stereophotographs was taken at 3 and 9 months. The second series will be used to determine whether any progression in the scoliotic curves can be detected using photogrammetry, and to develop guidelines for further radiological investigation.

2. THE MEASUREMENT SYSTEM

2.1 Stereoscopic Camera System

Normally two cameras are used to obtain stereoscopic photography. However, as only one measuring camera (Rollei 6006 metric camera) was available at the time, a system of twin mirrors and camera attachment was designed and constructed using the mirrors from a mirror stereoscope. The system records a double image on each exposure. As patient backs are somewhat vertically rectangular in shape the two images fitted quite well on to the square film format of the Rollei camera.

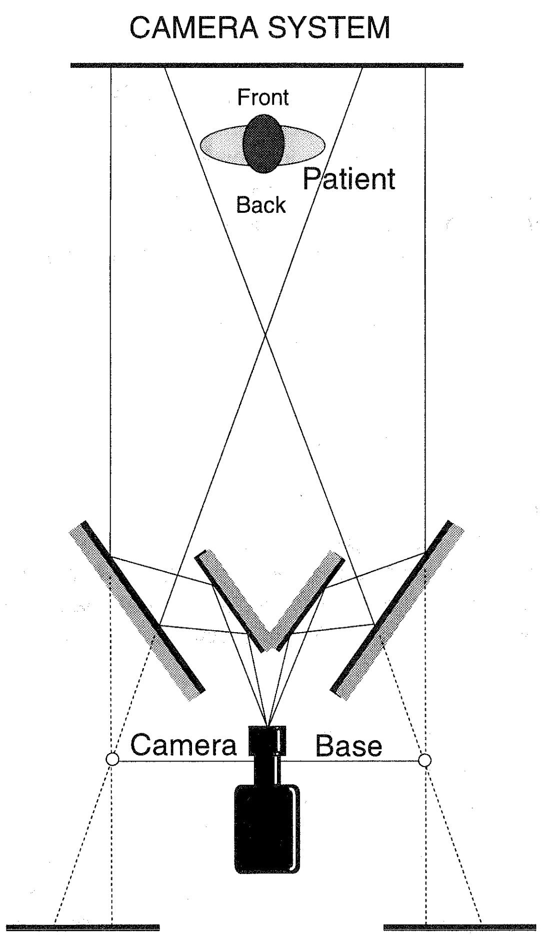

Fig. 1 Diagram of Camera System

2.2 Camera System Calibration

The camera system was calibrated against a test field in a school laboratory at a similar camera object distance to that which was used in the clinical examination room. While there were no discontinuities in the calibration results, the differences between the camera system determined values and actual test field values were not symmetrical, possibly caused by lack of flatness in the mirrors. To allow for this, a set of correction data for the model field was determined and recorded. The average correction was +1.4mm with a maximum correction of +6.3mm. Object coordinates of points subsequently measured with the system were then empirically modified according to the correction data before they were used for back shape determination.

2.3 Patient Reference Frame

A frame was made in an attempt to ensure the patient returned to a "standard" position each time the patient was photographed. The frame was made of stainless steel and attached or fixed to the wall of one of the examination rooms in the hospital. The frame contained adjustable chin support, shoulder pads and lower cross bar for hands to grip. Reference marks were placed around the frame to enable orientation of the stereo model.

The frame and reference marks were calibrated in situ. A Rollei 6006 metric camera was used to acquire imagery (nine photographs) and image coordinates were measured in a Zeiss Planicomp C100 analytical plotter and processed using a bundle adjustment to deliver calibrated coordinates of the frame.

2.4 Expected Accuracy of the Camera System

The patients were about 2m from the stereoscopic camera system which had a nominal principal distance of 50mm and an effective base of 0.3m. A value of 0.01mm was adopted as the image measuring accuracy. Simplified geometry was used to estimate the accuracy which could be achieved with the system. The initial estimates based on geometry were 1-2mm in planimetry (perpendicular to camera axis) and 3-4mm in depth (parallel to camera axis).

3. THREE DIMENSIONAL RECONSTRUCTION

3.1 Image Acquisition

Before being photographed, the spinous processes on the patients backs were marked with special X-ray markers to show up on both normal photography as well as X-rays to enable correlation at a later date. Details such as date and patient name were displayed on the frame so that each individual photograph could be clearly identifiable. A grid was projected on to the patient's back using a slide projector in order to help stereoscopic viewing by giving the generally featureless back some texture. Colour reversal film (slide film) with as ASA rating of 200 was used under normal fluorescent lighting conditions. The photography was very reliable with clear images resulting in all cases.

3.2 Object Restitution

Three dimensional shape of the back and positions of the markers were measured and recorded using a Zeiss C100 Planicomp analytical plotter. In most situations the shape was measured as a digital elevation model with a 25mm mesh size. The mesh data was supplemented with additional points and features such as high point of the rib hump and the "valley" down the middle of the back. Once the height data was collected it was modified according to the correction data obtained through the system calibration procedure. The measurement phase was straight forward but time consuming. This would no doubt be improved with the acquisition of digital photogrammetric software.

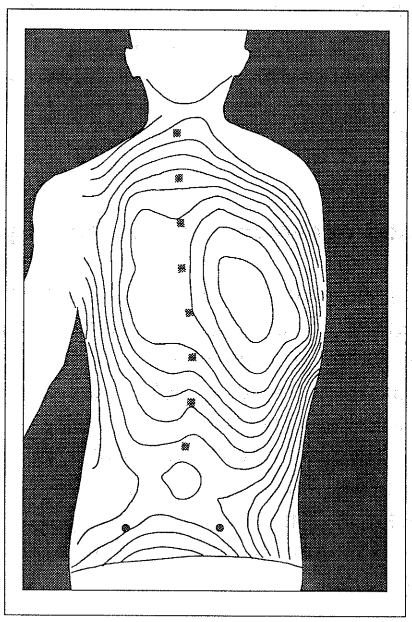

Fig. 2 Contour Map of Back

4. RESULTS

The initial sets of three stereophotographs have been analysed and contour maps created for each of twelve patients, for all three sittings. To determine a measure of reproducibility these contour maps were then subtracted from one another (sitting 1 - sitting 2, sitting 1 - sitting 3, sitting 2 - sitting 3). The subtracted contour maps give a further contour map showing the differences between sittings. A perfect match gives a flat surface with no contours.

A number of points (15) were then taken at random from each of the subtracted contour maps to give a measure of overall point accuracy. The data are listed below:

Event	Average (mm)	Std Dev (mm)
Sitting (1-2)	4.1	3.6
Sitting (1-3)	4.5	4.8
Sitting (2-3)	3.4	2.9
Total	4.0	3.9

From the data we see that as the patient becomes more familiar with the positioning frame (sitting (2-3) the reproducibility improves to 3.4mm with standard deviation 2.9mm. The overall point accuracy of the differenced contour maps (or repeatability) was 4.0mm with a standard deviation of 3.9mm.

These values appear reasonable when the flexible nature of the human body is considered.

5. CONCLUSIONS

It would appear that the stereophotogrammetry technique developed under this project is reproducible and accurate to within 3-4mm. In its current state the technique is not yet viable as a screening tool but it is very useful as a research tool.

It is proposed to set up two prospective clinical trials to assess the change in back shape in patients with idiopathic scoliosis undergoing surgical intervention. The first is a randomised study of braced versus non-braced change in back shape in patients who undergo costoplasty as part of their surgical stabilisation. The second is to document the reduction in rib prominence in idiopathic scoliosis patients undergoing surgical stabilisation and to compare the amount of correction in those patients who undergo costoplasty as a part of their surgical procedure versus those who have surgical instrumentation and fusion only.

6. ACKNOWLEDGEMENTS

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7. SELECTED BIBLIOGRAPHY

D'Amico, M., Merolli, A. and Santambrogio, G.C., (Editors), 1995. Three Dimensional Analysis of Spinal deformities. IOS Press, Amsterdam.

Karara, H.M., (Editor), 1989. Non-Topographic Photogrammetry, 2nd Edition. American Society for Photogrammetry and Remote Sensing.

Slama, C.S., (Editor), 1980. Manual of Photogrammetry, 4th Edition. American Society for Photogrammetry.

Turner-Smith, A.R., Harris, J.D., Houghton, G.R. and Jefferson, R.J., 1988. A Method for Analysis of Back Shape in Scoliosis. J. Biomechanics, 21(6), pp 497-509.