VERY CLOSE RANGE PHOTOGRAMMETRIC TECHNIQUE FOR OBTAINING THREE-DIMENSIONAL COORDINATES OF CRITICAL LANDMARKS ON THE INFANT HEAD

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INTRODUCTION

The risk of head injuries to infants and children, during various activities, can be greatly reduced with the use of a properly fitted and protective helmet. In order to construct these helmets extensive impact testing is necessary. Therefore, the development of accurate and representative infant headforms, to be used in the impact testing, is essential. The headforms, presently being used for helmet impact testing are mainly of the adult head. These headforms do not suitably represent the distinct infant and children head shapes. The construction of a suitable infant headform requires accurate information on the size, shape and geometrical dimensions of the infant head. Schneider et al. (1987) and Snyder et al. (1975,1977), as part of their study on the prevention of infant head entrapment accidents, used standard measurement techniques (anthropometers, callipers and measuring tapes) to obtain data on the size and shape of children heads and necks. Schneider et al. (1987) also used the close range photogrammetric technique known as Direct Linear Transformation (DLT) to identify critical contours and landmarks. Unfortunately the data gathered was not extensive enough. The purpose of this study was to validate a very close range photogrammetric DLT technique for obtaining accurate three-dimensional (3D) geometrical information on the infant head.

REVIEW AND THEORY

The use of standard measurement techniques poses several problems when trying to collect accurate data. Firstly, instrument and technician error must be dealt with. Then there is also the problem of manipulating the instruments to fit the contours of the head. These problems are then compounded by the squirming infant or child. The use of the DLT close range photogrammetric technique (Marzan et al., 1975) can eliminate these problems. The technique involves initially filming or photographing a calibration object, containing known control points, with two or more arbitrarily positioned cameras. The calibration object is then replaced with an "unknown" object so that it occupies the same calibrated space, and without altering the camera setup the filming or photographing is repeated. The 2D coordinates of the points on both the calibration object and the "unknown" object are then digitized and inputted into the DLT algorithm to calculate the 3D coordinates of the markers on the "unknown" object. The control points are used to solve for the DLT parameters which will define camera position and orientation and correct for film deformation and lens distortion errors. The number of control points is not as important as the distribution of these points. Few control points well distributed throughout the object space produce accurate results (Wood et al., 1986). The number of DLT parameters (11,12, 14 or 16) used will depend on the degree of error correction desired. However, it has been shown that use of a greater number of parameters does not significantly improve reconstruction accuracy (Wood et al., 1986; Murphy et al., 1990). The construction and measurement of the calibration object can drastically affect accuracy. As shown by Andre et al. (1990), the use of a well constructed and accurately measured calibration object markedly reduces reconstruction error. Several researchers have reported acceptable reconstruction errors for close range photogrammetric setups (Wood et al., 1986) and for very close range photogrammetric setups (Murphy et al., 1990; Leroux et al., 1990). The accuracy of reconstruction is limited by the digitizing board (± 0.4mm). The use of 35mm film as opposed to 16mm film, may improve the accuracy of digitization due to the larger image and finer grain

PROCEDURES

A calibration object, resembling a cage (38.4cm x 38.4cm x 38.4cm), containing 48 control points was built. This calibration object, big enough to contain an infant head, was placed in the centre of a square table, which had four synchronized Minolta 35mm cameras mounted at each corner (Fig 1 and Fig 2).

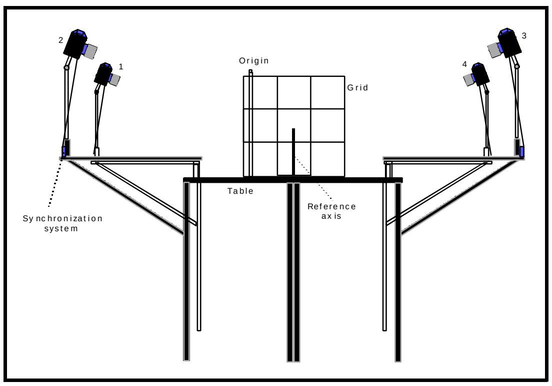

Figure 1 Photographic setup showing table, cameras and calibration object (side view).

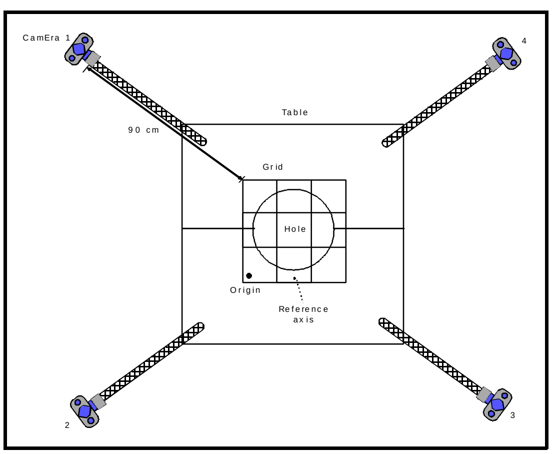

Figure 2 Photographic setup (top view).

The hole at the centre of the table allows the infant to place his/her head in the calibrated space. The control points on the calibration object were measured manually to an accuracy of 0.5 mm. These measurements were then verified with the use of a three-dimensional digitizer. The ascertain the validity of this technique reconstructions of known points were carried out. Three reconstructions were performed: calibration object (all 48 points), two points suspended in the centre of the calibration object and four points on a model of an infant head. For the infant head model the calibration object was filmed by itself first, and then removed and replaced by the head model. The film negatives were converted to slides and digitized(Scriptel). All reconstructions were performed using 11 DLT parameters and 8 and 16 control points.

RESULTS AND DISCUSSION

Table 1 presents a summary of the preliminary results. The accuracy and precision (reconstruction errors) were determined for the X, Y and Z coordinates of each reconstructed point. The accuracy and precision range from 1.1 ± 0.9 mm to 4.3 ± 1.4 mm for reconstruction with 8 control points, and from 1.1 ± 0.8 mm to 3.8 ± 0.7 mm for reconstruction using 16 control points. The accuracy and precision is similar for both control point conditions. This is consistent with the results presented by other researchers (Murphy et al., 1990; Wood et al., 1986). The slightly better to markedly better results for reconstruction of the calibration object, compared to the other two reconstructions, is most probably due to a high actual measurement error. The actual measurements of the points on the calibration object were more easily obtainable and therefore more accurate then the other known points. The reconstruction errors for the calibration object are slightly higher than those reported by other researchers using very close range photogrammetry (Leroux et al., 1990; Murphy et al., 1990).

Table 1 Reconstruction error (mm). Standard Dev. ( )

Control points

Reconstruction	8 CP			16 CP		
	X	Y	Z	X	Y	Z
Cage	1.1 (0.9)	1.2 (1.0)	1.6 (0.8)	1.2 (0.9)	1.3 (1.0)	1.1 (0.8)
Center Points	4.3 (1.4)	2.6 (1.8)	1.1 (0.8)	3.8 (0.7)	2.7 (1.0)	1.4 (1.3)
Head Model	2.3 (1.6)	2.4 (1.3)	2.1 (1.9)	1.7 (1.7)	2.8 (1.4)	2.1 (1.7)

This difference is most probably due to the difference in measurement error of the calibration points. Leroux et al. (1990) reports a measurement error of only ± 0.02 mm. However, an error of 1.1 mm in a field of 384 mm is an acceptable error (0.5%). Appropriate camera settings and proper digitizing will also help improve accuracy. A blurred image will hamper digitization and add to the error. Fig. 3 demonstrates a reconstructed image that can be obtained using this very close range photogrammetric DLT technique.

The use of this technique will eliminate instrument and technician error inherent in manual measurement. In addition, since the photographs are taken simultaneously, the infant or child need only be still for a few brief seconds. This is more realistic then asking an infant to remain still for longer periods of time.

The proposed, very close range photogrammetry DLT technique will provide accurate 3D information of the infant head which can then be used to construct suitable headforms. For improved accuracy, care should be taken when measuring the actual coordinates of the calibration cage, adjusting the camera settings and digitizing the 2D images.

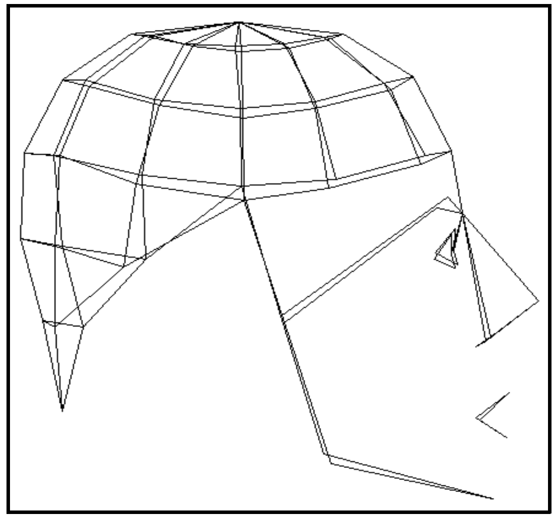

Figure 3 Reconstructed head model.

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