3D PHOTOGRAMMETRIC ANALYSIS OF THE LOAD-BEARING FOOT

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INTRODUCTION

Surpisingly little is know about how the plantar aspect of the foot deforms while walking. Motion of the bones or shape of the foot during load-bearing has been studied using video fluoroscopy [1] laser scanning phtogrammetry [2] or modelled from static poses using finite element techniques [3]. Also, pressure under the foot is regularly measured, but how the plantar surface changes during weight-bearing is unknown despite being relevant to balance, shoe design and orthothic prescription for the normal and pathological foot.

Close-range photogrammetry (CRP) has been used extensively in medical applications, such as craniofacial mapping [4] and scoliosis screening [5] to obtain three-dimensional data and provides a feasible method for measurment of the plantar surface of the foot during gait. Advantages of this method over existing imaging techniques are that it is (i) non-contact and non-invasive, (ii) provides instantaneous imaging, (iii) is highly accurate, and (iv) allows for dynamic analysis of structures. This paper presents the development and application of a novel CRP technique for studying the dynamic 3D shape of the plantar surfuace of the foot during gait.

METHODS

The system consisted of four still frame digital cameras mounted on a sturdy aluminium frame, synchronized using a LANC Shepherd remote control device, and a rigid photogrammetric control frame. The control points were mounted underneath a glass plate that was embedded in a raised walkway. Distortion due to the glass was calculated and accommodated for in subsequent data reduction. The non-metric cameras were calibrated to determine the principal offset points (X_p,Y_p), the principal distance (PD), radial distortion parameters (K_1, K_2,K_3), the lens alignment (P_1,P_2) and in some instances, the dynamic fluctuation. This was achieved using a detachable target board with known coordinates of control targets.

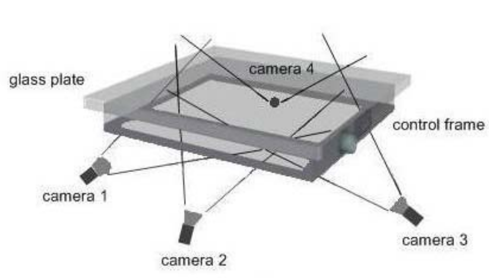

Figure 1: Schematic of close-range photogrammetric system

The 3D plantar surface of the foot during load-bearing was recorded during standing, walking at fast and slow pace using the cameras' video mode (25Hz). Anthropometric landmarks were identified and marked with a fine-tipped black permanent marker following the method of Garcia-Hernandez (05) following palpation by an experienced manipulative physiotherapist: The marks were circular and in plain black colour.

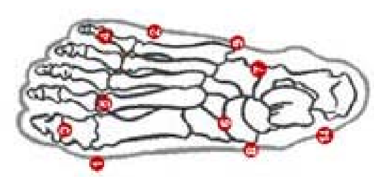

Figure 2: Anatomical landmarks (Garcia-Hernandez, 2005)

Image digitizing and data processing was performed using Australis® photogrammetric software. This provided the x,y,z coordinates of the object point and sensor calibration data were obtained using bundle adjustments.

RESULTS AND DISCUSSION

The average difference between true and measured 3D distances of the target board was 0.43±0.01mm. This accuracy was obtained within 300mm depth of field, allowing sufficient space to observe the foot prior to heel strike through to toe-off. Results of the 3D reconstruction of the foot are pending.

CONCLUSIONS

This technique showed that non-metric camera and off-the-shelf software can provide accurate 3D measurement of anthropometric landmarks and 3D mapping of the foot surface contours.

ACKNOWLEDGEMENTS

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