VALIDATION OF A 3D SURFACE RECONSTRUCTION METHOD: A PRELIMINARY STUDY

[1]Fan Gao, [2]Guangkun Li [2]Zhigang Wang and [1]Susan Kapp

[1]Department of Health Care Sciences, UT Southwestern Medical Center at Dallas, TX, USA
[2]BioCAX LLC., 1411 Chirsta CT, Sewickley, PA USA

INTRODUCTION

Precise three-dimensional (3D) measurement of human body is essential for prostheses and orthoses design and fabrication. Traditionally, plaster bandage was used for molding and producing negative mold of the residual limb. However, it is a laborious, time-consuming, costly and discomfort procedure, and the quality of the resultant product is subject to practitioners' experience with poor repeatability and controllability. Close range photogrammetry (CRP) has been widely applied in industry to measure shapes and locations. CRP has also found its applications in the medical field especially in reconstructing 3D anatomical structures [1-4]. Recently, we have developed a method based on CRP using only entry level single-lens reflex (SLR) digital camera to reconstruct the 3D surface [5]. Though its performance based on theoretical calculation is satisfactory, its validity remains unknown. The objective of this study is therefore to attempt to validate the photogrammetry based system via comparing to other methods/systems.

METHOD

Apparatus: A positive plaster mold was made from a trans-tibial prosthetic socket and a turntable was used to hold the plaster mold. Eleven markers were placed randomly and used to align the points clouds obtained from both CRP and standardized digitization. An electro-magnetic 3D motion sensor was attached to a plastic stylus and used to digitize the 3D surface of the plaster mold (3D Guidance trakSTAR, Ascension Technology Corp. Burlington, VT USA). The electro-magnetic sensor was selected due to its ease of use and good accuracy (i.e. .4 mm). A Canon Digital SLR camera with resolution of 18 mega pixels, equipped with 18-55mm focus lens was used. In addition, a tripod and remote control were used to reduce the motion artifacts.

Procedures: a brief procedure is provided and detailed description of the method based on photogrammetry could be found in our previous study [5]. The camera was carefully calibrated using a checkerboard. Pictures were then taken at an increment of ~20 degrees by rotating the turntable and in total eighteen pictures were obtained. The feature points were found and matched in the two consecutive images to reconstruct the 3D surface in a world coordinate. The 360 degrees of 3D point cloud was constructed by retrieving the projection matrix in the world coordinate by automatically identifying the point matches in subsequent images. The stylus was used to cover the surface of the plaster mold and corresponding 3D coordinates were registered. In addition, the centers of the eleven markers were digitized to facilitate point clouds alignment.

Data Analysis: 3D point cloud was obtained using both methods. The 3D point cloud was cleaned (i.e. eliminating outliers) and then interpolated to allow performance evaluation. Image processing and data analysis was conducted in MATLAB (Mathworks Inc. MA, USA)

RESULTS

The scale of the photogrammetry point cloud was recovered using the feature point matched between the two measurements. The point clouds were aligned and overlapped using correspondence between pre-defined feature points and then fine adjusted using the ICP algorithm. Both of the point clouds were converted to a cylindrical coordinates and interpolated to quantify the measured error. The error shows Gaussian distribution with 1 sigma error of 1.25 mm.

DISCUSSION AND CONCLUSION

Digitization using electro-magnetic 3D motion sensor has been validated in previous studies. In the current study, this method was used to serve as a reference. The preliminary results showed that the 3D point clouds obtained via these two methods are in good agreement. In summary, the performance of photogrammetry based 3D surface reconstruction is satisfactory. Further performance evaluation compared to existing commercial systems (e.g. Canfit™, Vorum Corp. Canada) is underway.

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