Low-cost, Quantitative 3D Structural Imaging of the Nose and Other Facial Features Using Open Source Software

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Abstract

Objectives: In functional nasal airway surgery, quantitative 3D imaging is often used to create volumetric representations of human facial features. Quantitative 3D imaging can be used to rigorously track changes in nasal morphology and provide numerical outcome measures. However, commercial 3D imaging systems are expensive. This study describes how open-source software and consumer cameras can be used to perform this task inexpensively and efficiently.

Study Design: Computer-based research study

Methods: 123D Catch developed by Autodesk was used to generate the 3D representation of the printed silicone nasal model derived from a CT scan. The 3D model provided a Lambertian reference standard to consumer digital cameras including the Samsung Galaxy S5, Canon Rebel XTS, and Canon Rebel T5i. Diffuse illumination was used. Total image number was varied along with imaging using surface registration landmarks. Point clouds were created and CloudCompare, an open source program, was used to compare each camera reconstruction with the CT data from which the model was derived. Next, imaging of a subject’s ears and noses were performed, and software measurements were compared with those directly measured using a micrometer.

Results: Results have shown that 123D Catch accurately provided 3D nose and facial representations after mesh comparison with CloudCompare by merging and aligning point clouds created from the 123D Catch and CT data. In addition, 123D Catch can clearly reconstruct both inanimate objects and facial attributes with excellent accuracy.

Conclusion: 123D Catch can be used as an inexpensive, alternate method to 3D reconstruct the nose compared to commercial 3D programs.

Introduction

There are numbers of clinical imaging software packages and camera systems that can capture 3D volumetric representations of human facial features, useful for reconstructive and cosmetic surgery [3, 4, 5, 7]. Quantitative 3D imaging can be used to track changes in nasal morphology and provide numerical measures. They have enhanced functionality to allow surgical planning and digital manipulation. However, current methods are expensive, with costs well over $1000 and first-rate systems approaching $100,000 [1, 9, 10]. To counter the present 3D rendering technology, a cost effective approach is being utilized with open source software. The core of this process is the actual 3D imaging software, which is available through multiple open source avenues. We evaluated one open source software package through a detailed process of evaluation and identified Autodesk 123D Catch as a viable alternative to these commercial systems. We also hope to use consumer-type photographic systems to accomplish this as well. To evaluate the ability of our approach, two tests were conducted: a visualization test to determine whether this software can produce realistic 3D images, and a quantitative test to determine the accuracy of 123D Catch.

Methods and Materials

Step 1: Preliminary Observation

Visualization Test: The first step was to use a digital camera to obtain photographs and test the visual accuracy of the software, Autodesk 123D Catch. The computer reconstruction provided excellent aesthetic results. On closer inspection, this outcome provides viable options such as a means of quantitative measurement to look at changes in structure following reconstructive surgery. Quantitative accuracy of these images must now be determined in the next experimental steps.

Step 2: 3D Model Template Using CT Data

Step 3: 3D Printing of Silicone Nose Model

Fabrication of Nose: Dot density on the silicone model were applied as surface registration landmarks for photography (Fig. 5). Dots were originated from Sharpie fine point pens.

Photography of Nose: Proper diffused lighting conditions were established to have high quality images created from poster board and tissue paper (Fig. 6).

Step 4: Autodesk 123D Catch to 3D Image

Computer Reconstruction of Nose: Autodesk 123D Catch was used for the 3D reconstruction of the silicone model and human facial features (Fig. 7, 8). Samsung Galaxy, Canon Rebel XTS, and Canon Rebel T5i obtained images at numerous angles and controlled heights. Photogrammetry created the 3D model.

Step 5: Point Cloud Comparison

Diagram Keys: Samsung Galaxy S5 (A), Canon Rebel XTS (B), Canon Rebel T5i (C)

Figure A-C: The figures represent cloud-cloud distance comparisons of the models generated by Autodesk 123D Catch and CT data. Colors represent values of distance deviation. Lower numbers represent better accuracy. Green = no deviation. Blue = negative deviation. Red = positive deviation.

Mean Gaussian Distribution Fitting Values of the 3D Models Created by Various Camera Methods

Comparison of Direct Measurements vs. Software Measurements of the Silicone Nose Model

Comparison of Direct Measurements vs. Software Measurements of Volunteer #2

• Autodesk 123D Catch can be used as an inexpensive, alternate method to 3D reconstruct the nose and other facial features compared to commercial 3D programs.
• Autodesk 123D Catch is an easy way for surgeons to broadly perform 3D imaging
• Limitation: 123D Catch is not a morphing software, so surgical planning may not be useful for rhinoplasty. However, this program would be well-suited to follow post-operative outcomes and calculate changes in geometry following any facial operation.

Conclusions

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References