WHAT FACTORS EFFECT THE ACCURACY OF SOLID MODELS MADE FROM CT DATA?

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INTRODUCTION

Computer models of bones are essential tools for research in orthopaedics, preclinical analysis of orthopaedic implant designs, and in computer-aided surgery. In these applications, solid models of bones are routinely created from computed tomography (CT) scan data; however, there are few studies [1-3] that have quantified the effects of the process parameters, on the error of the resulting geometry. The purpose of this study was to determine the magnitude of the error in solid models generated from CT-scan data and to which factors the error was most sensitive.

METHODS

This study compared the volumes of simple shapes derived from their measured dimensions and their segmented CT data. Cubes and cylinders were constructed from aluminum 6063 and polyurethane (PU) foam and their geometric dimensions were measured. Solid models based on the measured dimensions of the pieces were constructed with Unigraphics NX 2.02 from EDS, Plano, TX. In addition, the pieces were CT scanned (120 kV, 30 mA ,GE Litespeed[16] CT scanner from GE Medical Systems, Waukesha, WI at the University of Wisconsin Hospital), and their geometry was reconstructed by segmenting (Mimics 8.11 from Materialise, Ann Arbor, MI) the grey values of CT data that represented the density of the shapes.

The volumes of the shapes reconstructed from the CT data were normalized to the volumes of the solid models constructed from the measured dimensions. The effect of 7 factors at 2 levels each on the normalized volume of the segmented models was investigated using a one quarter fractional factorial design. 32 (2^{7-2}) treatments were run without replication in random order. The 7 factors and each of their high and low levels were:

1. CT-scan axis orientation: parallel and perpendicular to sample axis;
2. CT-scan slice thickness: high (1.25 mm) and low (0.625 mm);
3. CT-scan slice spacing: high (1.25 mm) and low (1.625 mm);
4. Density: high (aluminum 6063, 2700 kg/m^3) and low (solid rigid PU foam, 320 kg/m^3);
5. Fill: full and hollow (wall thickness 3.18 mm);
6. Feature: with and without a 3.3 mm wide by 6.6 mm deep, centered slot; and,
7. Shape: cube (25.4 mm^3) and cylinder (25.4 mm diameter x 25.4 mm height).

RESULTS

The mean of the normalized volumes of all the segmented shapes was 96% (79%-115%). A normal probability plot of the effect estimates from the fractional factorial analysis found that density was the only main effect that was likely to be important. The normalized volume of the aluminum and PU samples were 105% (93-115%) and 88% (79-96%) respectively. In contrast, all the highs and lows of the other main effects differed by less 2% (95-97%). In Table 1, the qualitative effects of the scanning parameters on the segmented models are demonstrated.

Table 1. The Effects of Scanning Parameters
a) Scan Axis Perpendicular to the Sample Axis.

b) Scan Axis Parallel to the Sample Axis.

DISCUSSION

Even though, normalized volume is a relatively insensitive result, density was found to be an important main effect. Volumes were under and over-estimated for low and high density pieces respectively. The scanning parameters had a qualitative effect on the models; however, it remains to be investigated, if a more sensitive result would find quantitative effects.

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