Towards Estimating the Uncertainty Associated with 3D Geometry Reconstructions from Medical Image Data

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3D-image based geometries are increasingly used for patient-specific visualization, measurement, physics-based simulation and additive manufacturing. Computed Tomography (CT) is a common imaging modality used to obtain the 3D geometry of objects through X-ray images taken from different angles to produce cross-sectional images along an axis. Levine *et al.* (1,2) developed a reference phantom, or "NIST phantom", to help control for variations in scanner settings, noise and artifacts. Ideally, the geometry of the phantom would be extracted through the ISO 50 standard threshold-based segmentation, which states that the material boundary is set as the middle greyscale value between the background and material peaks in the greyscale value histogram (3). The purpose of this study is to examine the effects of image resolution on the uncertainty associated with 3D geometries reconstructed from idealized and real CT images.

An idealized spherical reference phantom of known diameter was generated in CAD format used by AutoCAD. A CAD voxelization process was used to convert the CAD sphere into 3D greyscale images at various resolutions. These images were then used to study the effect of image resolution on measurement accuracy of the sphere diameter, measured via a sphere-fitting method. Next, an image stack of the NIST phantom, generated using a SkyScan 1173 CT scanner (Bruker MicroCT N.V. Kontich, Belgium), was resampled to various resolutions to allow for a similar accuracy study. Image stacks generated from the voxelized CAD sphere were devoid of artifacts, and as such, an ISO50 thresholding approach could be used with confidence. A similar ISO50 technique was also applied to the segmentation of the NIST phantom data.

During the CAD sphere voxelization process, the accuracy of measurement was 2% if 5 or more voxels were present across the sphere diameter. The measurement accuracy degraded to approximately 4% for a similar degree of voxelization when resampling the CT scan data of the NIST phantom. The main source of this inaccuracy appears to be related to the choice of segmentation threshold. Investigation of threshold choice suggests the ISO50 segmentation approach is not suitable for these CT images, which is in agreement with results in published literature (3).

Through an idealized image set (i.e. a perfect CT scan), we have shown that a measurement accuracy of 2% or less can be maintained down to a very coarse image resolution. Artifacts present in CT image data, whether from the physical object or the scanning process, can lead to worse accuracy. These artifacts may affect segmentation threshold choice during geometry reconstruction. In summary, this work is an important first step towards estimating the systematic uncertainty associated with 3-D geometry reconstructions that are utilized as part of image-based modeling applications.

Mention of commercial products does not imply endorsement by NIST.

References:

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