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# "High Resolution Extremity CT for Biomechanics Modeling"

A. Elaine Ashby, Hal Brand, Karin Hollerbach,
Clint M. Logan, H. E. Martz
Lawrence Livermore National Laboratory
Livermore, CA

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TITLE=LLNL High Resolution Extremity CT for Biomechanics Modeling

AUTHOR=A. Elaine Ashby, M.D., LLNL, Box 808, Livermore, CA 94551
AUTHOR=Hal Brand, LLNL, Box 808, Livermore, CA 94551
AUTHOR=Karin Hollerbach, PhD, LLNL, Box 808, Livermore, CA 94551
AUTHOR=Clint M. Logan, LLNL, Box 808, Livermore, CA 94551
AUTHOR=H. E. Martz, PhD, LLNL, Box 808, Livermore, CA 94551

ABSTRACT=With the advent of ever more powerful computing and finite element analysis (FEA) capabilities, the bone and joint geometry detail available from either commercial surface definitions or from medical CT scans is inadequate. For dynamic FEA modeling of joints, precise articular contours are necessary to get appropriate contact definition. In this project, a fresh cadaver extremity was suspended in parafin in a lucite cylinder and then scanned with an industrial CT system to generate a high resolution data set for use in biomechanics modeling.

KEYWORDS=Computerized Tomography, Biomechanics, Finite Element Analysis, Anatomy

TEXT=1. INTRODUCTION:
Lawrence Livermore National Laboratory (LLNL) has been a leader in development of large-displacement, dynamic finite element analysis for application to defense systems. Recently, work has begun applying these codes (especiallly NIKE3D1 and DYNA3D2) to biomechanical systems. Geometries of the anatomy are available in the form of medical CT scans or bone surface coordinates3. Because of the constraint of radiation exposure to patients, voxel size has not been fine enough to precisely define the soft tissue of ligaments or the articular surface of joints for contact problems in finite element analysis. Strategies that acquire surface data by progressive dissection are by their nature limited in definition of internal structure. To adequately define both bone and soft tissue geometries, another source for anatomical data had to be found.

There is also a great wealth of experience and expertise at LLNL in the field of Nondestructive Testing4,5,6. CT scans are one of the many forms of industrial radiography employed in defense applications7,8,9,10,11,12. If radiation dosage were not a consideration (as it is not in industrial applications), a major constraint would be lifted in obtaining a high resolution CT data set for geometries. Hence, it was decided to scan a fresh (previously frozen, but not fixed) archival cadaver limb.

2. METHODS:
The archived hand and forearm of a middle-aged white female were obtained from the Office of the Northern California Curator, via the Orthopaedic Biomechanics Instutite of Salt Lake City. The extremity was thawed and then immediately immobilized in parafin in a six inch diameter lucite cylinder so that it could be attached to a stage for scanning.

Projection data sets were acquired with an industrial CT system that employs a scintillator. The scintillator was viewed by a 14-bit CCD coupled with a mirror and transmission optics. Seven hundred twenty projection views over 360 degrees were acquired, each consisting of 1020 by 1020 pixels. The data was reconstructed into equilateral voxels of 142 micrometer dimension using a convolution back-projection algorithm and standard rho (ramp) filtering.

The x-ray source employed for this work was a conventional industrial x-ray tube with a tungsten anode operated at 100 kV constant potential. No x-ray filtering was employed.

3. RESULTS:
Contrast sensitivity on the CT images clearly resolves soft tissue from bone and cartilage, as well as fine structural detail in the trabecular bone. The skin/parafin interface is clearly resolved.

4. DISCUSSION:
The CT scans of the extremity that were obtained have more than met the expectations of the finite element analysts in providing a data set of appropriate detail for defining articular surface geometries and bone internal structural detail. The use of a fresh-frozen, thawed extremity provides minimal distortion from in vivo anatomy; the anatomy is far closer to in vivo than a fixed specimen would be, with the shrinkage in ligaments and cartilage that results from processing.

Parafin proved to be a less than ideal support material because of the diifficulty in managing hot parafin, and the propensity to form air voids when cooling. Fortunately, the voids do not directly impinge on the extremity, so do not degrade any of the surface geometries.

5. CONCLUSIONS:
Industrial CT systems can provide a level of detail for anatomical structure that is not available from medical CT scanners because of constraints to limit radiation to living tissue. When scanning time and radiation dose are not determining factors, much higher quality images can be produced. Thus, a new research tool is provided by scanning archival cadaveric material with industrial CT.

Future plans in CT development are to characterize our system with regard to x-ray and light scatter. Also, it is planned to reduce x-ray scatter effects by employing a low density foam support material in place of parafin in the container and by using suitable pre-collimation and filtering. It is also planned to perform the reconstruction with a cone beam algorithm13.

Near future plans also include scanning lower extremities and spine segments.

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