Analysis of Implants and Wood Based Products from CT-Data

Festkolloqium Parallel Computing: Algorithms, Applications and Architectures

on the occasion of the 60th birthday of Prof. Marian Vajteršík.

Karl Entacher
Content

- Some personal comments
- Analysis of Implants
  - Shoulder Prosthesis
  - Dental Applications
- Analysis of Wood from CT-Data
  - FEA of Wood
  - Wood Based Products
Some Personal Comments

- **1992**: Started to work on my PhD-thesis “quasi Monte Carlo Methods”
- **ParNum94**: Smolenice, Slovakia, 1994
  - First talk at a conference!
- **ParNum95**: Sorrento, Italy, 1995
  - Parallel Stochastic Simulation: Inversive Pseudorandom Number Generators
- **ParNum96**: Gozd Martuljek, Slovenia, 1996
  - On the Relevance of Splitting Properties and the Compound Method in Parallel Applications of Pseudorandom Number Generators
- **ParNum97**: Zakopane, Poland, 1997
  - Analyzing Streams of Pseudorandom Numbers for Parallel Monte Carlo Integration
- **ParNum00**: Bratislava, Slovakia, 2000
  - Further Remarks on Long-Range Correlations among LCGs
- **ParNum02**: Bled, Slovenia, 2002 (FHS)
  - A simple OMNeT++ queuing experiment using parallel streams.
- **ParNum05**: Portoroz, Slovenia, 2005 (FHS)
  - Selection of Good Lattice Points Utilizing a Cluster
Some Personal Comments

- **1992 – 2001**: Research Assistant at the University of Salzburg
  - FWF - P9285 P11143 P12654 P8303 P12441 ÖNB - 7576
    Peter Hellekalek, Gerhard Larcher
  - CEI - PACT WP5, FWF P13732
    Peter Zinterhof, Marian Vajteršic

- **2001 →**: Position at the Salzburg University of Applied Sciences
  - Continued with FWF P8311-MAT “Quasi-Random Points: Theory and Software Development” together with Wolfgang Schmid
  - ParNum02: Bled, Slovenia and ParNum05: Portoroz, Slovenia

- **1995 →**: Lecturer at the School of Forest Products Technology & Timber Construction at the Salzburg University of Applied Sciences (FH-Salzburg)
Cooperation of HTB and ITS at the FHS with Paracelsus Medizinischen Privatuniversität PMU

Scientific Computing

Alexander Petutschnigg
CT – Materialanalysis
Finite Elemente Method

Werner Pomwenger
PhD - Student

Thomas Forte
Researcher

Michael Eichriedler
Diploma Student

Peter Schuller-Götzburg
Biomechanics
Project Leader PMU

Prim. Herbert Resch
Shoulder- and Ellbow Surgery

Rosemarie Forstner
Radiology

F. Watzinger
Landesklinikum
St. Pölten
Patient Specific Analysis of Shoulder Implants
Anatomy and Simple Movements

Abduction
Adduction

http://130.60.57.9/bewegungsapparat/index.swf (Mai 08)
Glenohumeral (shoulder) arthritis is a common source of pain and disability that affects up to 20% of the older population. Damage to the cartilage surfaces of the glenohumeral joint (the shoulder's "ball-and-socket" structure) is the primary cause of shoulder arthritis. http://www.leadingmd.com/ (May 2010)
Total Shoulder Rep. - Anatomical Prosthesis

Glenoid Component

Humeral Component

Humeral Head Component

http://fly2india4healthblog.wordpress.com/ (May 08)

Delta CTA™ Reverse Schulter Prothese

http://www.mybones.com/
http://www.shoulderdoc.co.uk
TSA - Total Shoulder Arthroplasty
TSA - Total Shoulder Arthroplasty
TSA - Total Shoulder Arthroplasty
TSA - Total Shoulder Arthroplasty
Patient Specific Analysis of Shoulder Implants

FWF – Project L526-B05

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<th>Barbara</th>
<th>Franziska</th>
<th>Erich</th>
<th>Rudolf</th>
<th>Klaus</th>
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<td>55</td>
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3D Model
CT - Scans: Basis for 3D-Modelling
3D - Modelling - Segmentation
3D - Modelling - Surface Models
3D - Modelling - Smoothing
Virtual Surgery

*Basis*: different CAD - Objects

*Method*: Boolean Methods with different Templates
Virtual Surgery
Model of Medical Cement
3D-Model of an implanted Shoulder
FE - Analysis
Forces from Prof. F.C. van der Helm

% xyz-direction of passive forces:
% 0, 30, 60, 90, 120, 150, 180 degrees abduction
% gh-joint

\[ fy = [-18.235, 113.518, 28.819, -76.628, -175.082, -156.340, -76.685]; \]
\[ fz = [2.080, 34.012, 133.408, 148.241, 119.613, 57.398, 24.208]; \]

% xyz-coordinates point of application passive forces
\[ x = [17.273, 15.992, 14.724, 13.709, 12.869, 12.411, 13]; \]
\[ y = [1.921, 3.470, 4.990, 5.660, 6.461, 6.023, 5]; \]
\[ z = [6.023, 9.109, 10.698, 11.767, 12.326, 13.026, 12]; \]
Comparison with real Forces

G. Bergmann et al., Charité - Universitätsmedizin Berlin

In vivo glenohumeral contact forces – Measurements in the first patient 7 months postoperatively.

*J Biomech*, 2006

Fig. 5. Forces during flexion with and without 2 kg weight in hand. (1) 0–90° flexion with 2 kg in hand and back, (2) same activity without weight. Physiotherapist marks the height of elevation. For more information see Fig. 4.


http://internationalshouldergroup.org/
Coordinate System Adaptions

CT-Position
Boundary Conditions

Fixation of the Scapula, for example:

Material

Material Parameter

- Compacta
  
  Young’s Modulus: 2.2 GPa.
  Poisson’s ratio: 0.3

- Spongiosa
  
  Young’s Modulus: 0.2 GPa
  Poisson’s ratio: 0.26

- Medical cement (Polymethylmethacrylat)
  
  Young’s Modulus: 2.2 GPa.
  Poisson’s ratio: 0.3

- Implant (Polyethylene)
  
  Young’s Modulus: 0.5 GPa.
  Poisson’s ratio: 0.4
Recent Study 1: Simulation Arthrose

Angle from 65° to 45°
Need for HPC!

- Very complex models which need high computation time!
- Simulation of Standard Movements
  Simulation of Bone Remodelling
Results


Thanks: to ATOMIC GmbH for the possibility to calibrate the implants and the company Arthrex for CAD data of implants. For financial support we thank the Schoellerbank Austria and the Österr. Gesellschaft für Zahn-, Mund- und Kieferheilkunde ÖGZMK, Zweigverein Salzburg. The Project is supported by the FWF Translational Research Program L526-B05 and by the PMU -FFF Rise Project R-09/03/003-SCH.
Recent Study 2: Dental Implants

http://www.zahndoc-leugner.de/impla.html (Mai 09)
Recent Study 2: Dental Implants

- Again CT-Data as a Basis for Modeling
- Segmentation

Fig. 7: Maxilla segmentation

Fig. 8: Maxilla and bone augmentation mask
Recent Study 2: Dental Implants

- 3D - Models
- Wrapping und Smoothing
Recent Study 2: Dental Implants

- 3D – Model
Recent Study 2: Dental Implants

- Wrapping, Smoothing and Bone Block insertion

Fig. 10: Maxilla, wrapping and smoothing operations applied, and remodeling of augmented bone and bone block
Recent Study 2: Dental Implants

- Virtual Surgery

Fig. 11: Bredent Medical Blue Sky Implant System

Fig. 12: Maxilla with simplified implants positioned
Recent Study 2: Dental Implants

- 3D – Volume Models (ANSYS ICEM CFD 12.0)
  - Advanced CAD/geometry readers
  - Built-in geometry creation and repair tools
  - Geometry tolerant meshing algorithms
  - Mesh diagnostics

Fig. 13: Model meshed with volume elements

Fig. 14: Nodes in common at material transitions (maxilla/implant/abutment)
Recent Study 2: Dental Implants

- 3D – Volume Models (ANSYS ICEM CFD 12.0)
  - Advanced CAD/geometry readers
  - Built-in geometry creation and repair tools
  - Geometry tolerant meshing algorithms
  - Mesh diagnostics

Fig. 15: Maxilla insight (sinus) with implants and bone graft block

Fig. 16: Volume mesh of simplified implants and bone graft block
Recent Study 2: Dental Implants

• Boundary Conditions
  • Masticatory forces: Corresponding to the mean maximal forces given in table 3, Mericske-Stern et.al. J Prosth Dent, 84 (5), 535-547, 2000.
  • Z-axis: 96N (masticatory force)
  • Y-axis: 36N (protrusion)
  • X-axis: 13N (laterotrusion)

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s M. (MPa)</th>
<th>Poisson’s R.</th>
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<tbody>
<tr>
<td>Cancellous bone</td>
<td>1.370</td>
<td>0.30</td>
</tr>
<tr>
<td>Cortical bone</td>
<td>13.700</td>
<td>0.30</td>
</tr>
<tr>
<td>Titanium</td>
<td>103.400</td>
<td>0.35</td>
</tr>
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</table>

Table 1: Material properties

Fig. 17: Ansys FE model with applied forces
Recent Study 2: Dental Implants

- Results

Fig. 18: Stress distribution - cut through full model

Fig. 19: Stress distribution on maxilla (cranial view)

Fig. 20: Stress distribution - cut through bone augmentation

Fig. 21: Stress distribution on cortical bone graft block
Results


**Thanks:** to the company Bredent for CAD data of implants. For financial support we thank the Österr. Gesellschaft für Zahn-, Mund- und Kieferheilkunde ÖGZMK, Zweigverein Salzburg. The Project is supported by the FWF Translational Research Program L526-B05.
Recent Study 3: FEA of Wood
Recent Study 3: FEA of Wood
Recent Study 3: FEA of Wood
Wood Technology Results in General


Thanks: FWF P17434 "Generalised linear models for wood characterisation“ and L526-B05
Recent Study 4: Wood Based Prod. Analysis

**Wood Panels:** MDF, Particle (Chip) Board, OSB

Master Thesis at Dept. of Computer Science and a Cooperation of ITS and HTB

Simon Kranzer  
Karl Entacher  
Gernot Standfest  
Alexander Petutschnigg
Recent Study 4: Wood Based Prod. Analysis

**Sub µ-CT imaging:** MDF, Particle Board, OSB
Recent Study 4: Wood Based Prod. Analysis

**Goal:** Analysis of the Pore-Size Distribution
Method

sub-µ-CT DATA

preprocessing (filter) → SLICES → morphological opening → count number of elements per size-class

SE

increase size of given SE

change shape of SE

cumulative percentage per SE
Prototype implementations of the method showed that processing time increased dramatically with the size of the used structuring elements.
Parallel Investigations

Speedup using “Multi-level decomposition of Euclidean spheres” MLD
Parallel Investigations

Relative speedup when porting the matrix manipulation to a multicore CPU or GPU (Example: Cartesian Product)
References


Thanks for your Attention and Happy Birthday

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