Creating FE Models from CT Data

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Overwiew

Introduction to medtool

Setting up an FEA project

Hands-on

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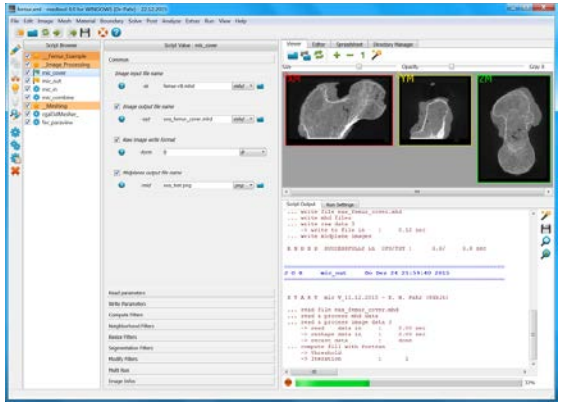
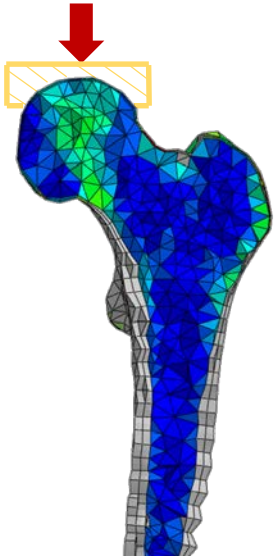
medtool Features

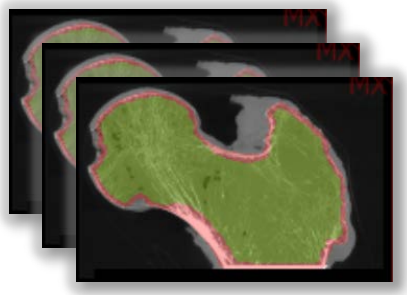
"From 3D images to FEA models"

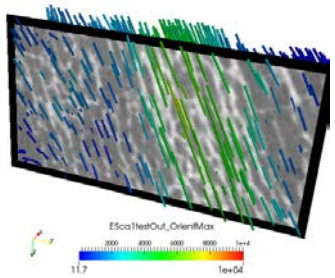
- image processing & analysis
- FEA meshing & modeling



- workflow (provenance) system
- (user) script manager
- parameter study (multi-dataset)
- report maker
- …







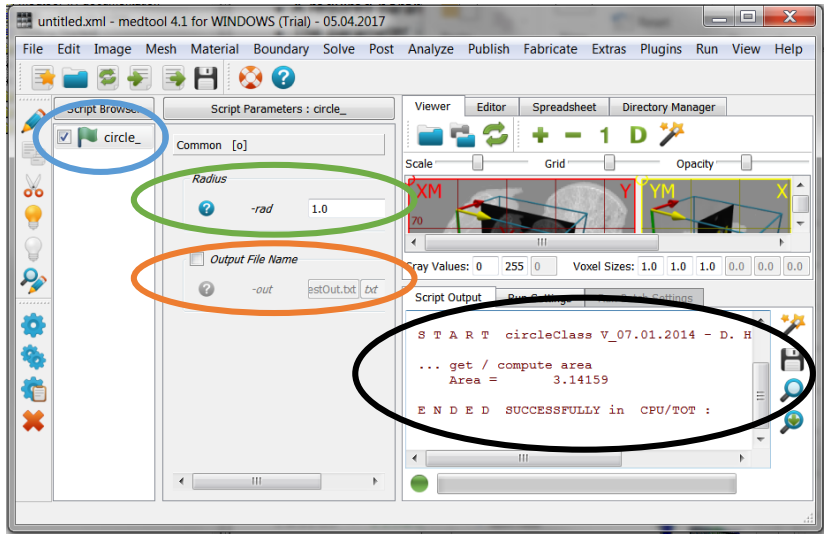
Idea behind medtool: Script Manager

- A simple script:

```
python circleArea.py -rad 15.0 [-out file.txt]
```

- Python Code:

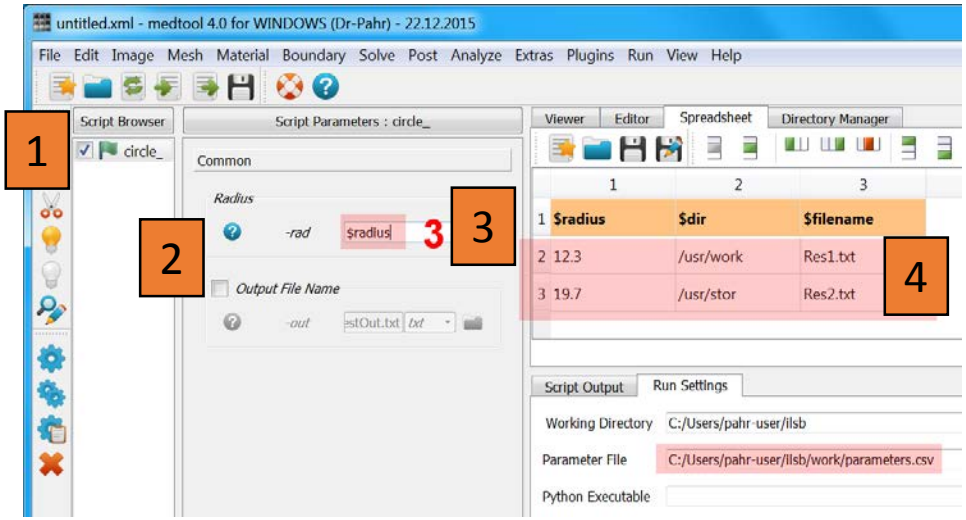
```
# ... get parameter from argument list
radius = float(argv[2])

# ... compute area
area = radius**2 * 3.14159

# ... output results
print "\n** Program: circleArea.py **"
print "    r =", radius
print "    A =", area, "\n"
```



Idea behind medtool: Provenance system

Need to know …

1. name of script (list)
2. (active) parameters of each script
3. parameter variable ($radius)
4. parameter values (CSV/XLS list → $radius = 12.3, …)



Getting Started with medtool

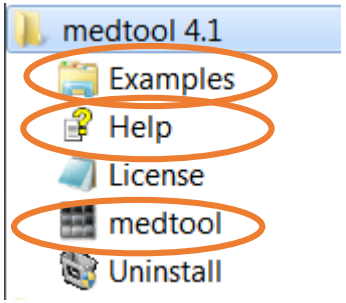
- Download the trail version:

  www.dr-pahr.at

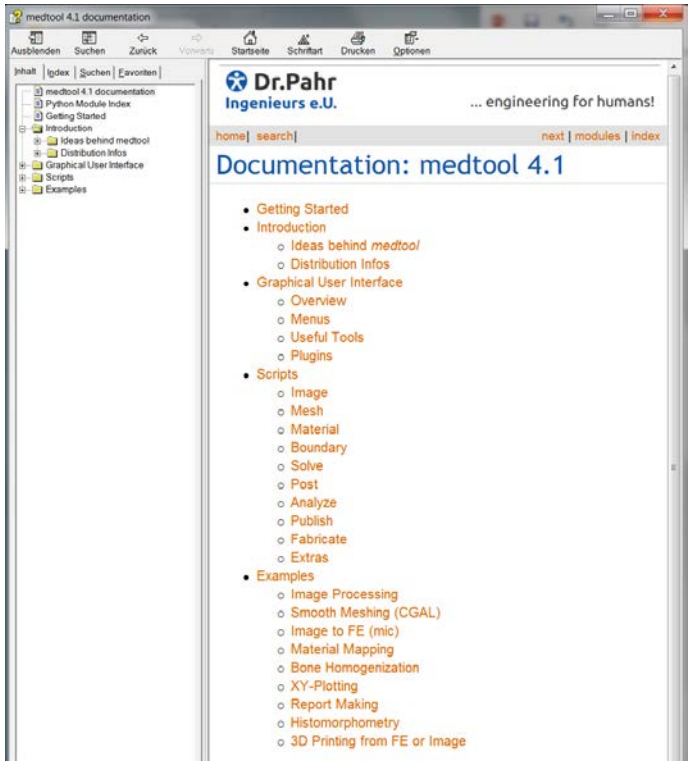
  User: home

  Pass: drpahR1=

- Have a look to the “Help”
- Work through “Examples”



medtool help



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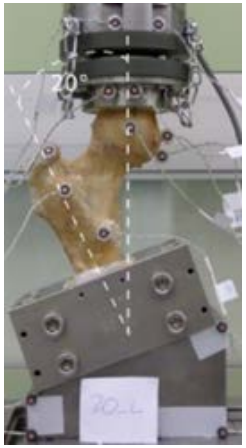
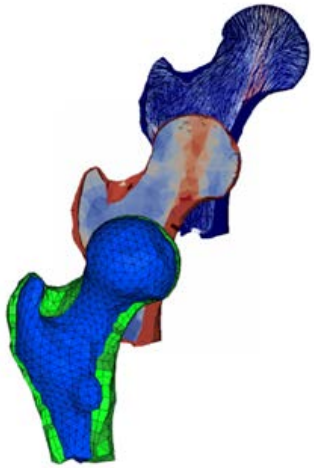
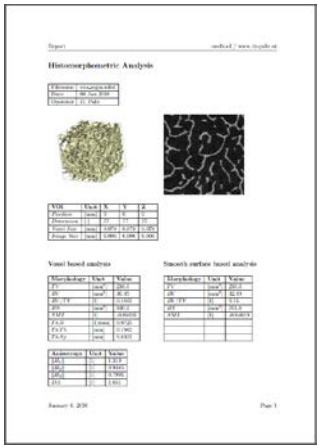
Project Definition Phase

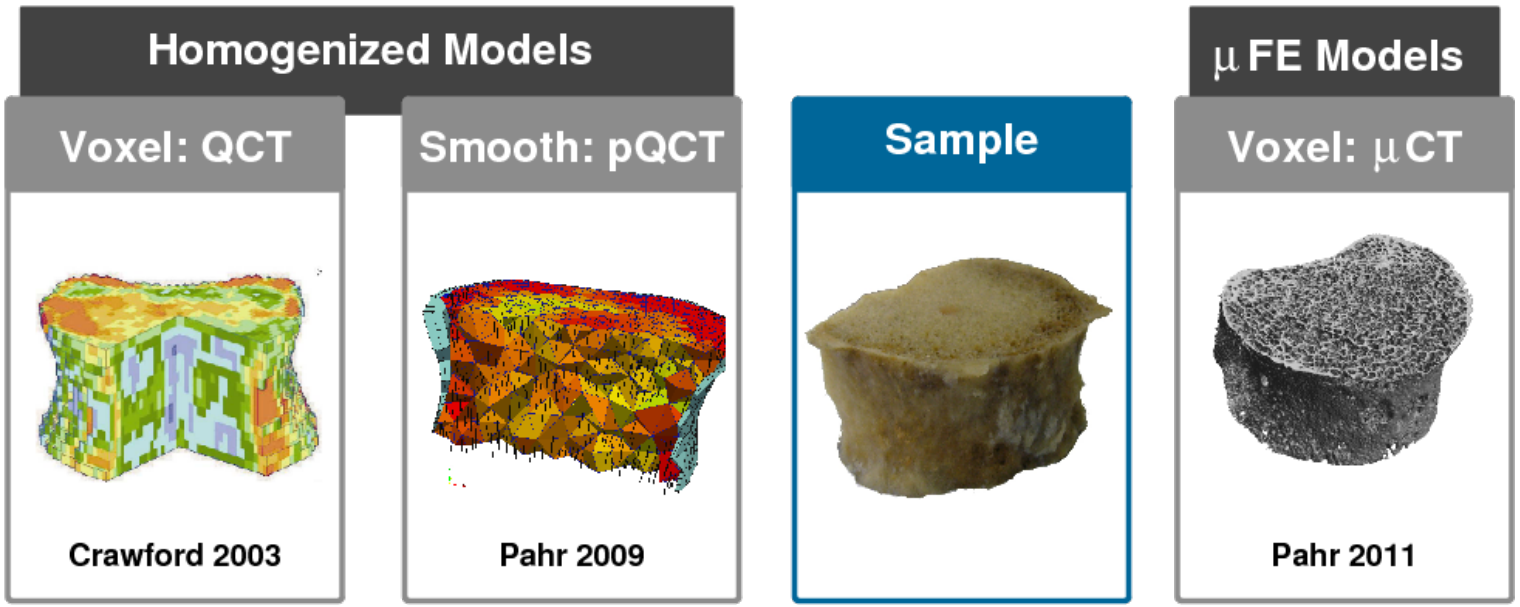
- scanning → alignment, type, storage, …
- mechanical testing → setup, measurements, …
- modeling strategy → tools, FEA type, …
- verification & validation → model checks, …
- documentation → data handling, reports, …







FEA Model Types



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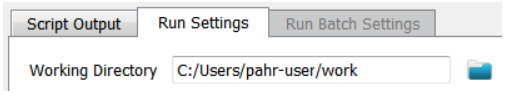
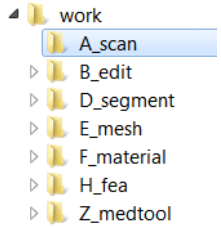
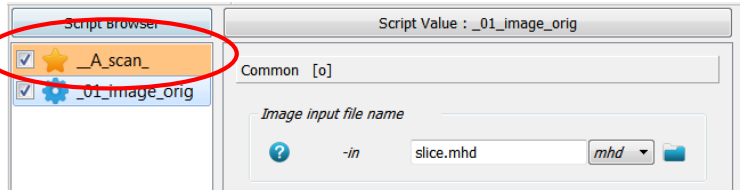
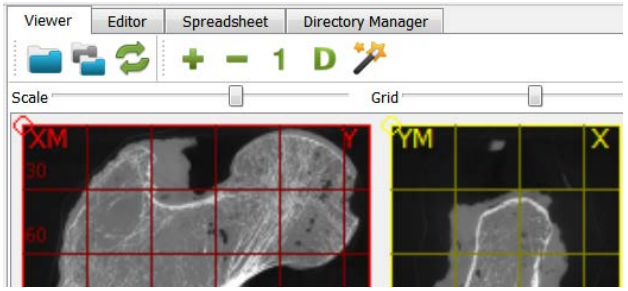
Step 1: Initial Setup & Data Check

- Set work directory
- Create directory structure
- Copy data files
- Make info script
- Check files with “Image → Processor”



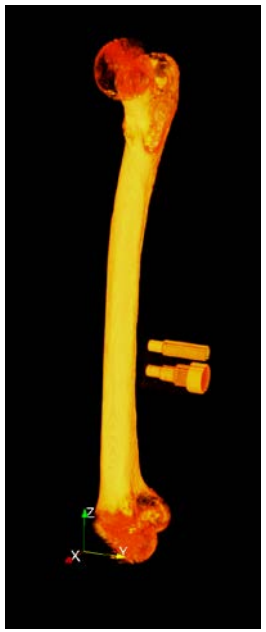






Step 2: Calibration

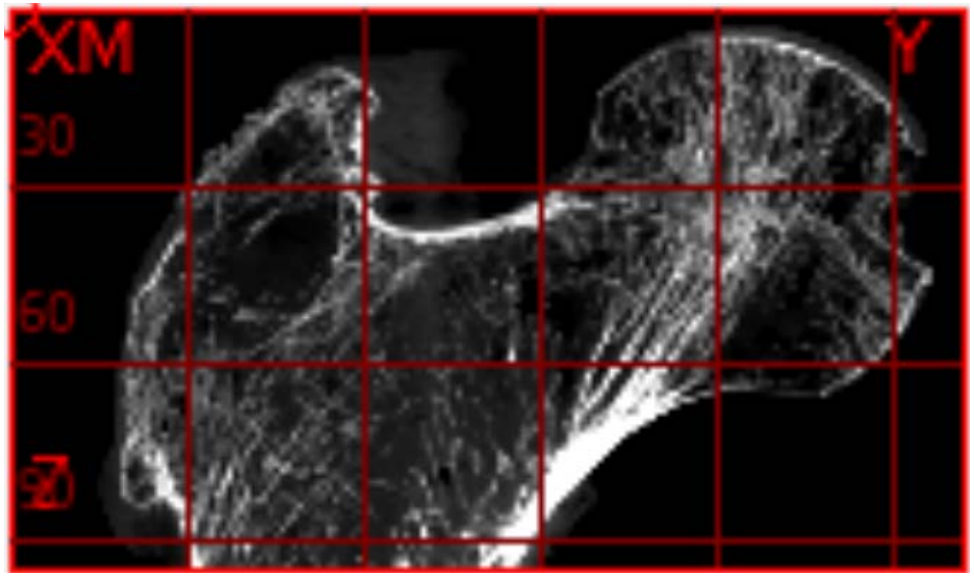
- CT gives HUs (Hounsfield units):
  - air ≈ -1000, water ≈ 0,
  - bone ≈ 500-1500
- FE needs BMD (bone mineral density):
  - from HU via phantoms
- or BV/TV (bone over total volume):
  - from BMD via calibration equation Dall'ara et.al. *Bone,* **2013**, *52*, 27-38
- Hint: 0-250 scaling
  - BV/TV = 0…1 gray value = 0…250

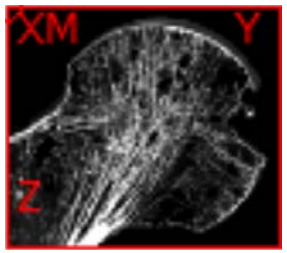


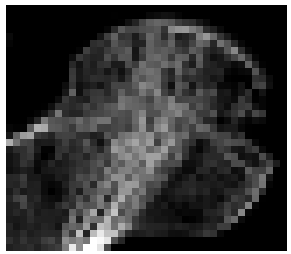
$$\begin{cases} \mu CT_{BV/TV}[\%] = 0.093 * QCT_{BMD}\dfrac{mgHA}{cc} + 1.077 & , \quad for -100 < QCT_{BMD} \leq 1064 \\ \mu CT_{BV/TV}[\%] = 100 & , \quad for\ 1064 < QCT_{BMD} \leq 1400 \end{cases}$$

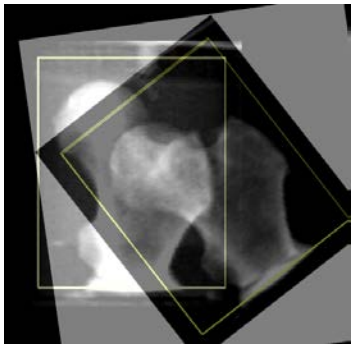
Step 3: Editing - Modifications

- crop ROI (region of interest)
- re-coarse image
- rotate/register image
- …





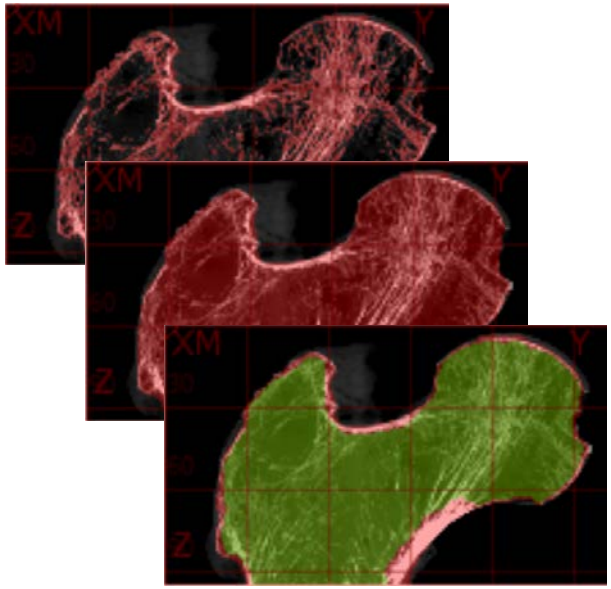


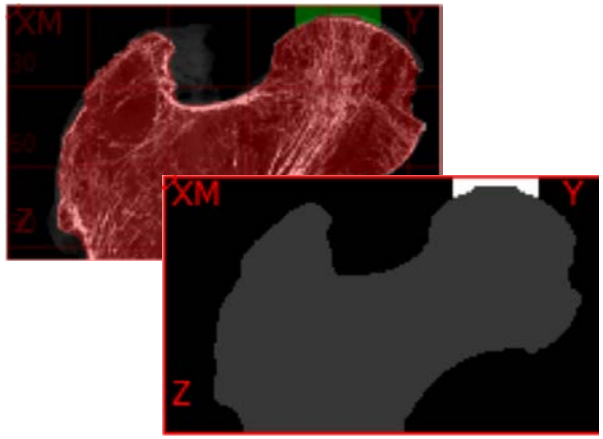


see medtool example "Image Processing"

Step 4: Segmentation

- automatic segmentations
  - fixed thresholds
  - “fill” regions outside & thickness
- interactive segmentation
  - “labeling” by hand
  - e.g. with Fiji, Slicer, …
- further modifications …
  - embedding

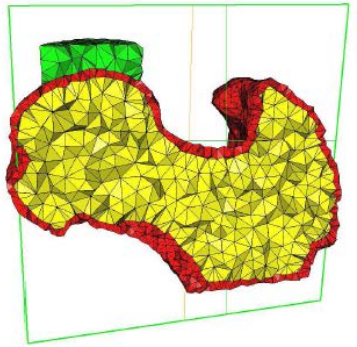


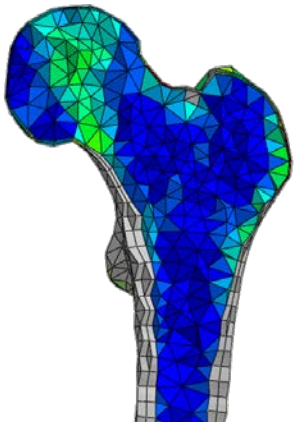


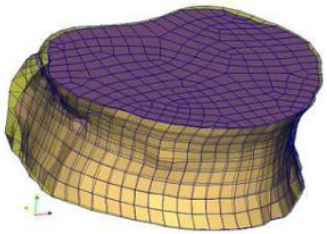
see medtool example “Image Processing”

Step 5: Meshing - hFE

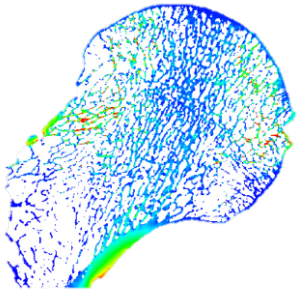
- Block meshing (multi-material)
- 2D or 3D meshing
- cortex meshing (bone mesher)
- smooth or voxel mesh
- micro and macro meshes
- convert image formats

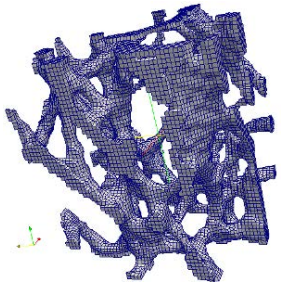


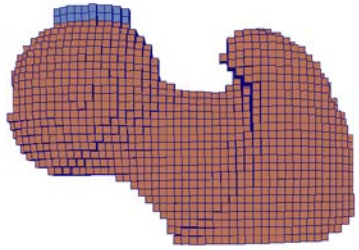




see medtool example "Image to FE" and "Smooth Meshing (CGAL)"







Step 6: Material Mapping

- map gray-values to elasticity
- direct → voxel models
- interpolated → smooth models
- mapping law:

Orthotropic model (Zysset)

$$E_i = E_0\,\rho^k\,(m_i^2)^l \qquad \frac{E_i}{\nu_{ij}} = \frac{E_0}{\nu_0}\,\rho^k\,(m_i\,m_j)^l$$

Isotropic model

$$m_i = 1, \qquad E = E_0\,\rho^k, \qquad \nu = \nu_0,$$

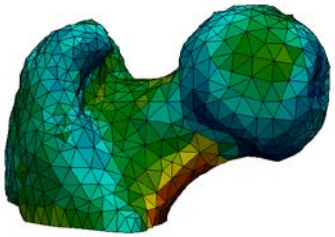
calibration parameters:

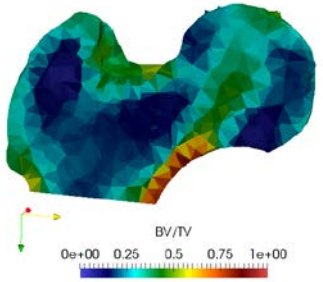
model)

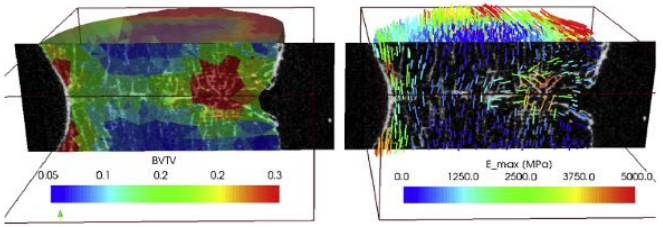
model)

see medtool example "Image to FE" and "Material Mapping"

Interpolated mapping

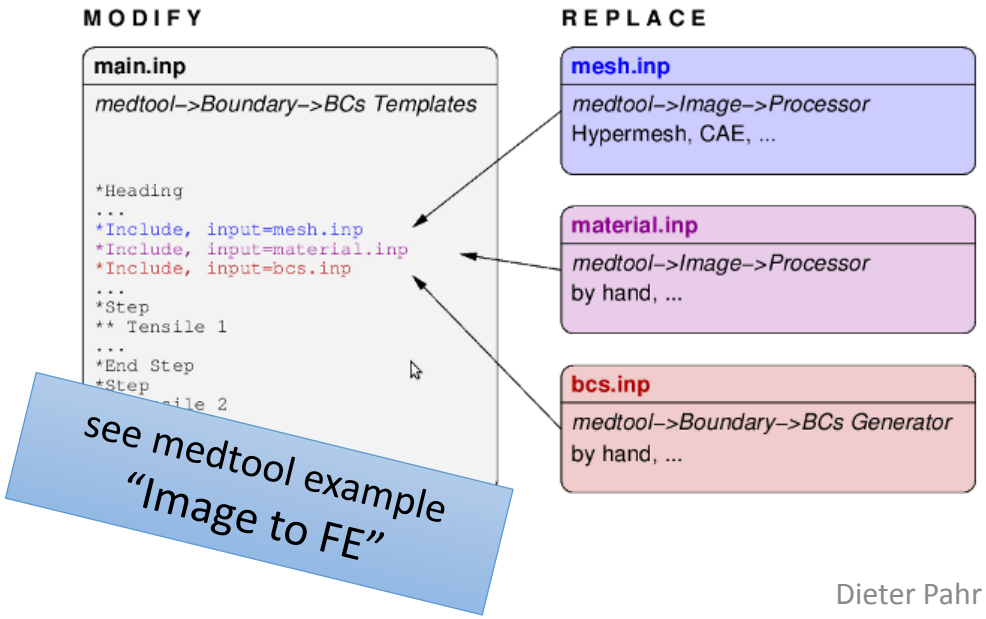


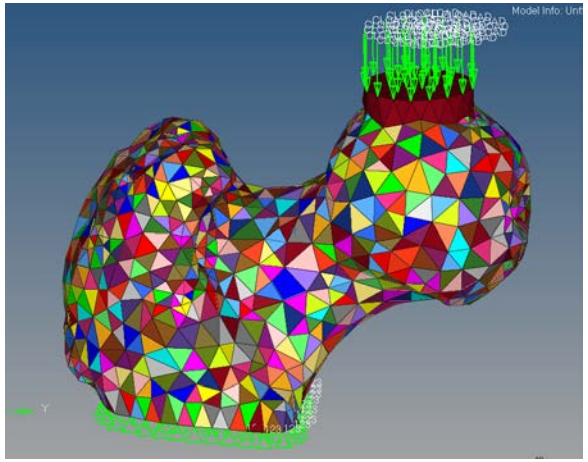




Step 7: FEA Modeling – Pre-processing

- creating solver input decks → Abaqus/Calculix format
- medtool philosophy: “includes”
  - mesh → automatically
  - material → automatically
  - loading → via node sets
  - main file → by hand or external pre-postprocessors

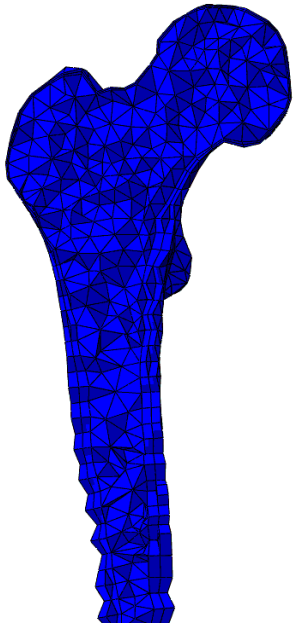




Step 7: FEA Modeling - Results

Analyzing FEA results:

- read solver output files via scripts
- use medtools XY-plot , Excel, …

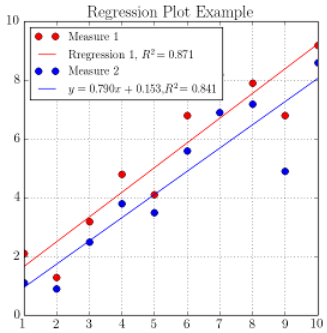


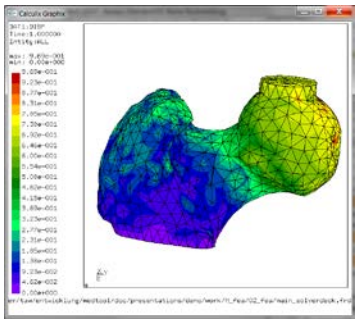
Viewing FEA results

- external post-processors
- Abaqus, HyperWorks, Paraview, …

```
XYZ; SWB;    [  0   0   0 ]
XYZ; SEB;    [  4   0   0 ]
XYZ; NWB;    [  0   4   0 ]
...
U  ; SEB:Step-1;    [ 3.0494E-03 1.8416E-13 0.0000E+00 ]
   ; SEB:Step-1;    [ 1.0000E+00 -2.4258E-13 -6.3974E-12 ]
                    [ 0.  0.  0. ]
```

see medtool example "Bone Homogenization"





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Do you have any questions, remarks, …

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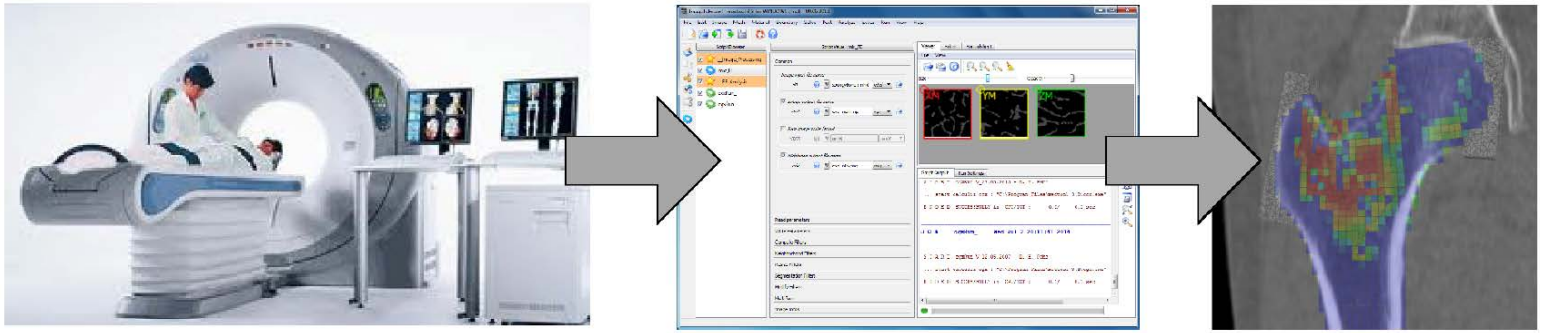
CT based FEA:

- Challenge: “Individualization”
- → automatization, parametrization, …
- Choose the right tool for your task!



Thanks for your Attention!

Contact

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