Towards Modelling of Trabecular Bone Microstructure

SSIP 2008 PROJECT 20

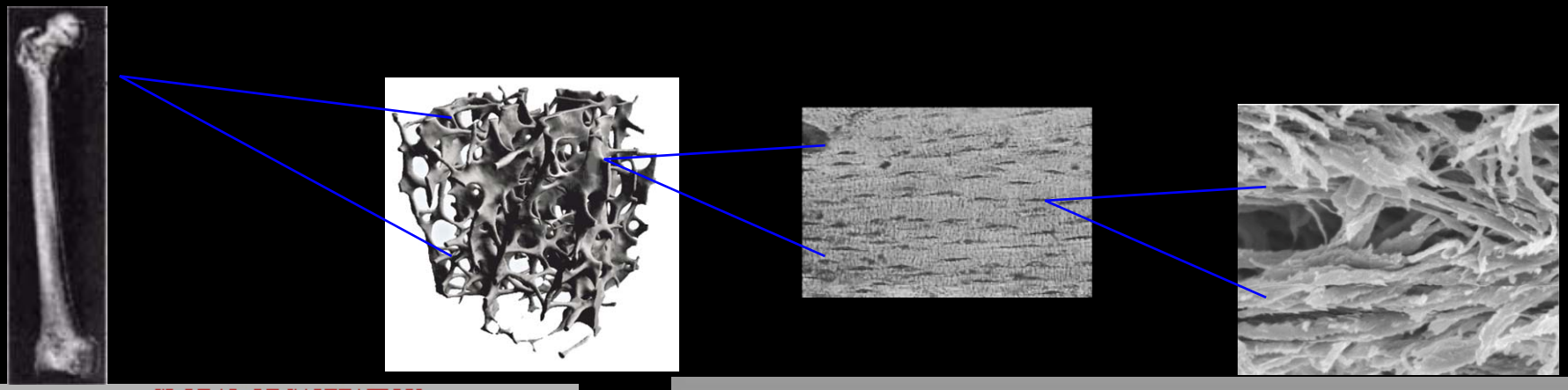
Outline

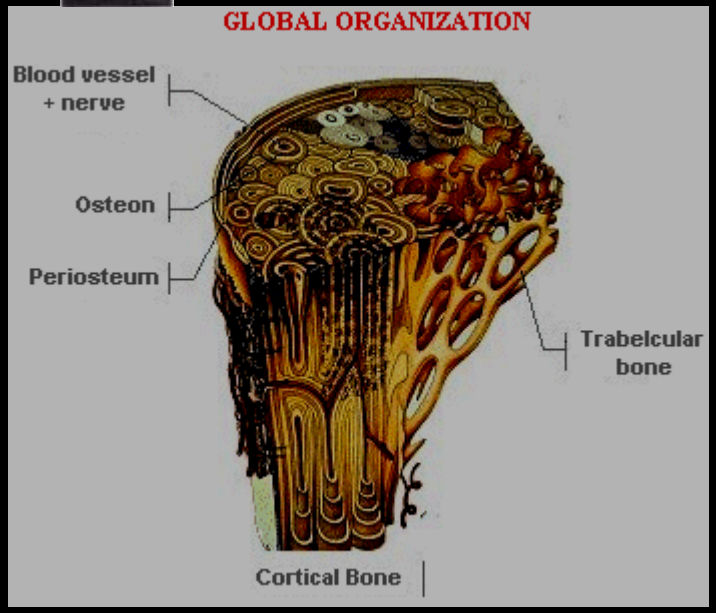
- Myths behind Bone
- Need for peronalized bone analysis
- Method and Materials
  - Materials
  - segmentation and Mesh generation
  - Finite Elment Analysis
  - Elastic property and Direction
- Results and Discussion

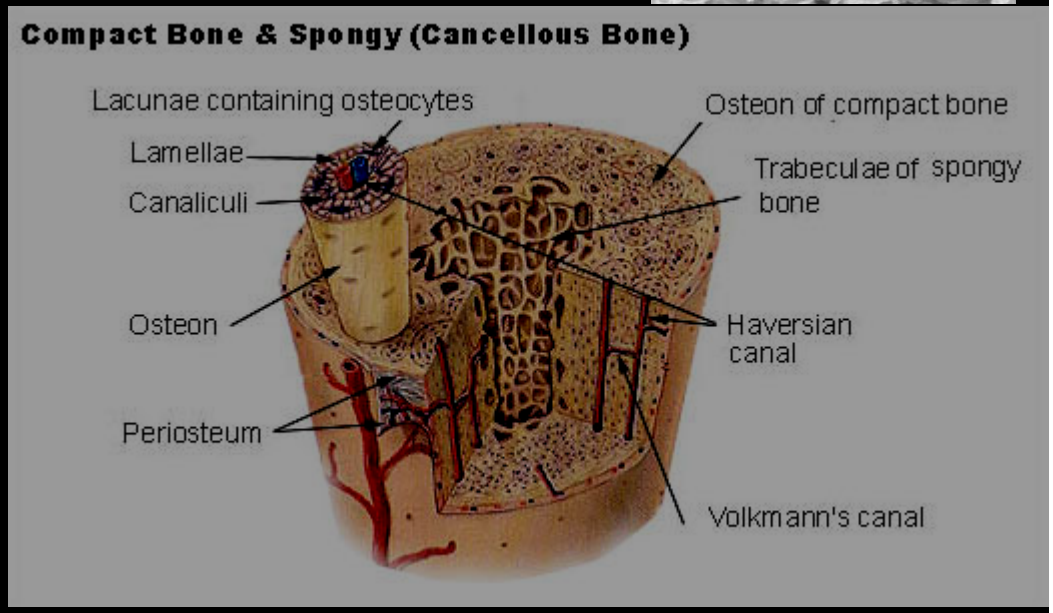
Objective

- Hypothesis: there exists a relationship between the direction (orientation) of bone and the forces it endures
- Challenges:
  - Trabecular bone is anisotropic, but how does the arrangement look like
  - Irregular geometry shapes
  - What kind of relationships between the architecture and mechanical properties

Insights of Bone

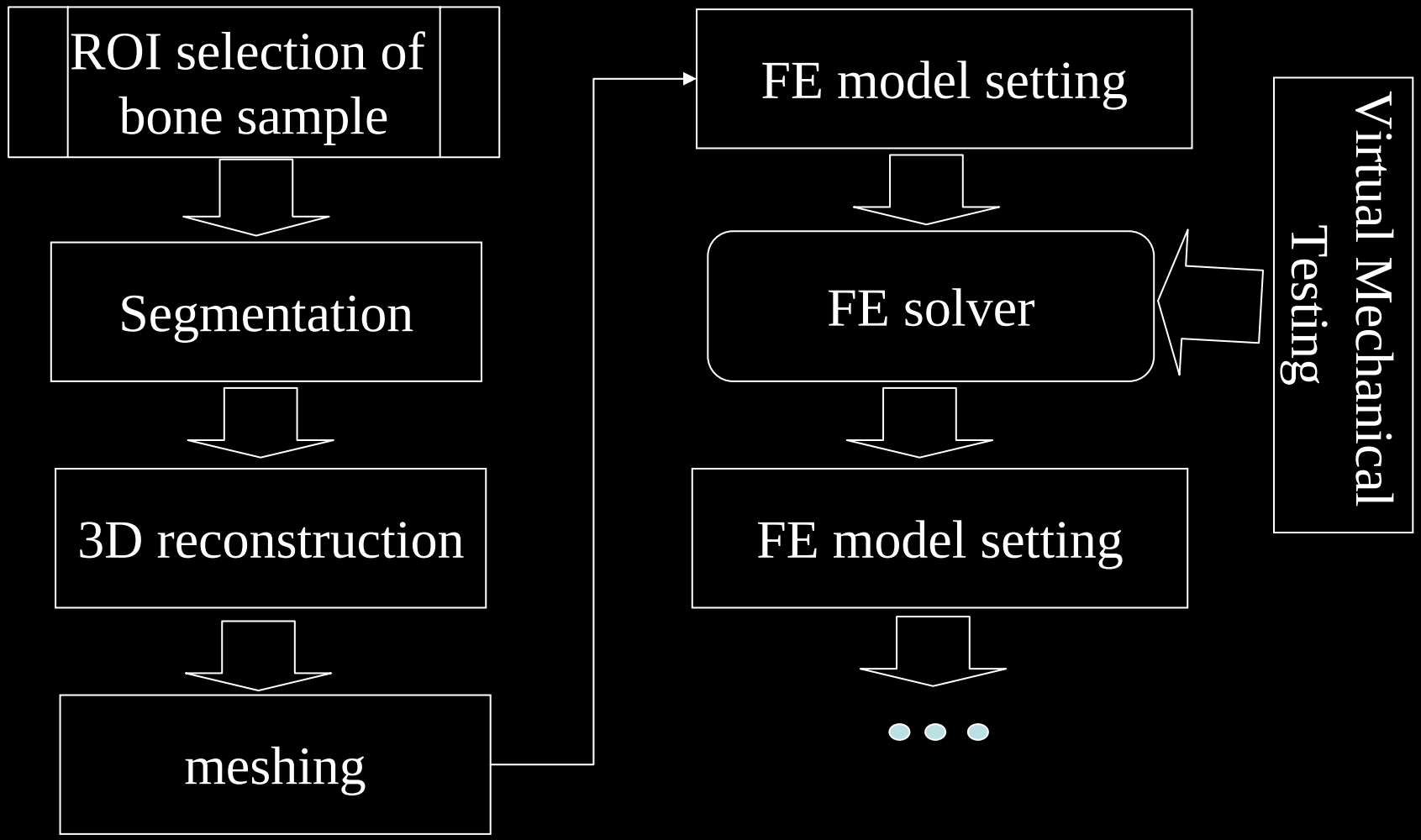




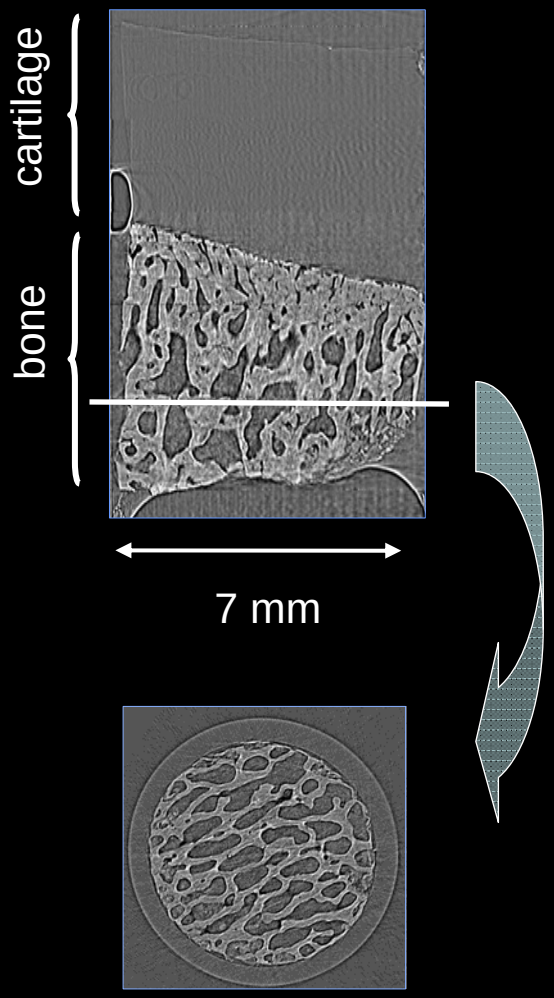


Ack, Bert van Rietbergen, Finite Element Modeling, The Physical Measurement of Bone, 475-510

Work flow


ROI selection of bone sample
Segmentation
3D reconstruction
meshing
FE model setting
FE solver
FE model setting
Virtual Mechanical Testing

Experimental data: tomography of a bone-cartilage sample

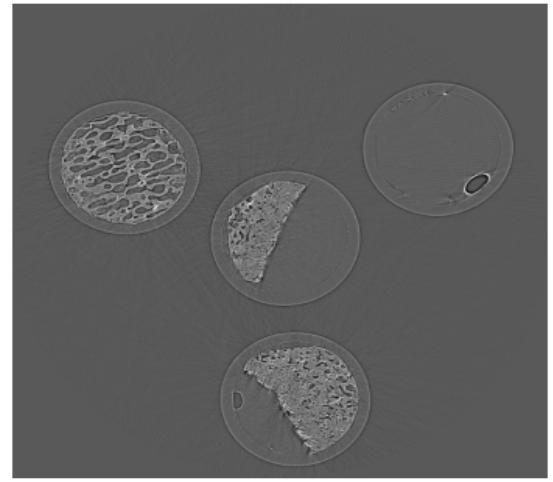


- Data acquired at:

  ID17 Biomedical Beamline
  European Synchrotron Radiation Facility (ESRF)
  Grenoble, France

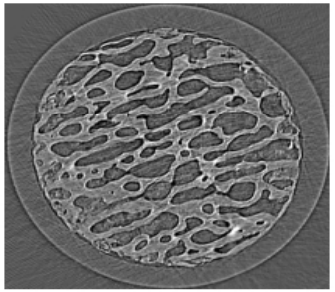
- Technique:

  phase-contrast imaging (propagation-based imaging technique)



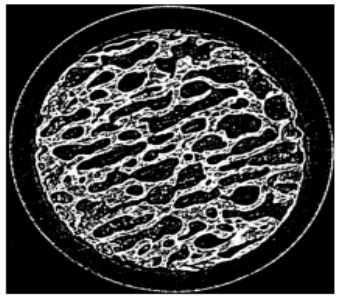
2D slice of 3D volumetric data

loading images

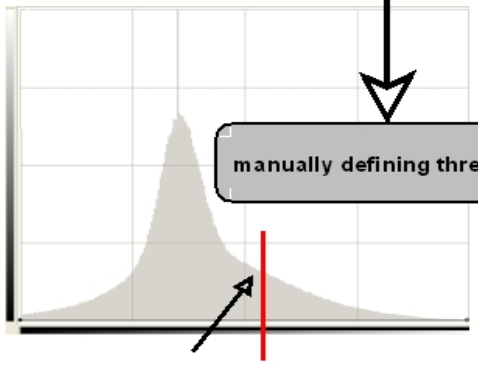


extracted VOI

manually selecting ROI



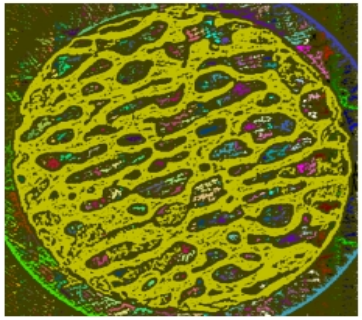
threshold result



threshold

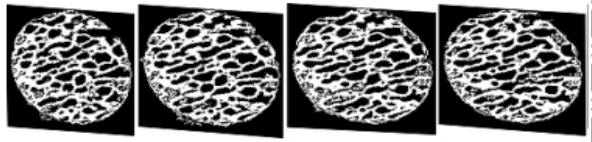
manually defining threshold

labeling connected regions



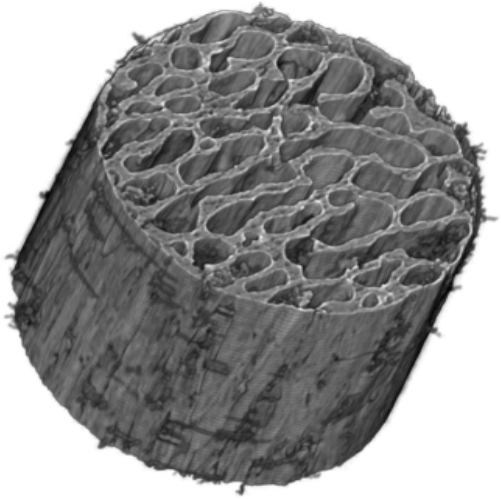
labeled slice

exctract larges area



size filtering result

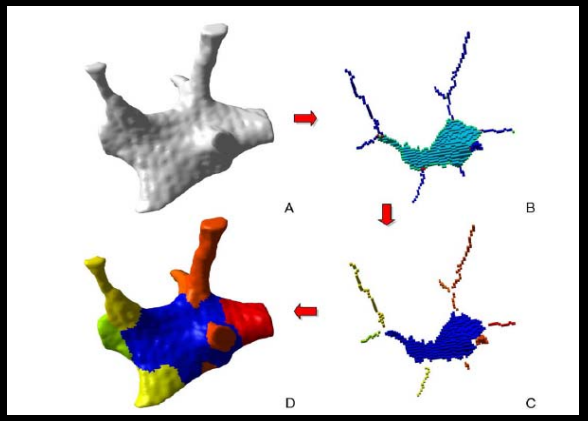
segmentation result

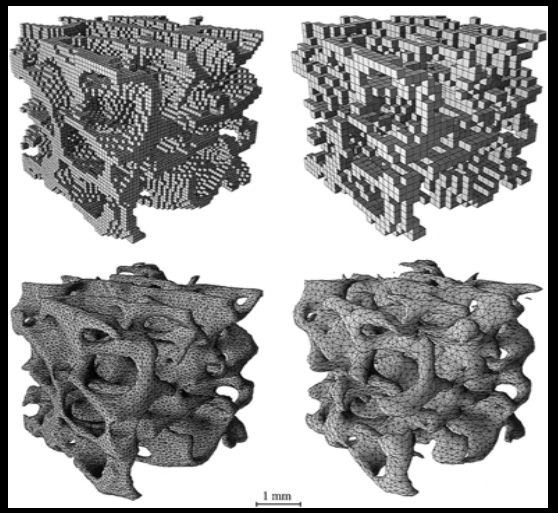


3D rendered volume

Meshing

- Divide the volume into elements
  - Surface meshing
    - Triangle shape elements (3 nodes)
  - volumetric
    - Cube shape elements (8 nodes)





The Materials

- Elasticity
  - Young's Modulus
  - Poisson Ratio

Table 1
Material properties of models

Property	Tissue	Holes
Young modulus [GPa]	6	0.006
Poisson ratio	0.3	0.3

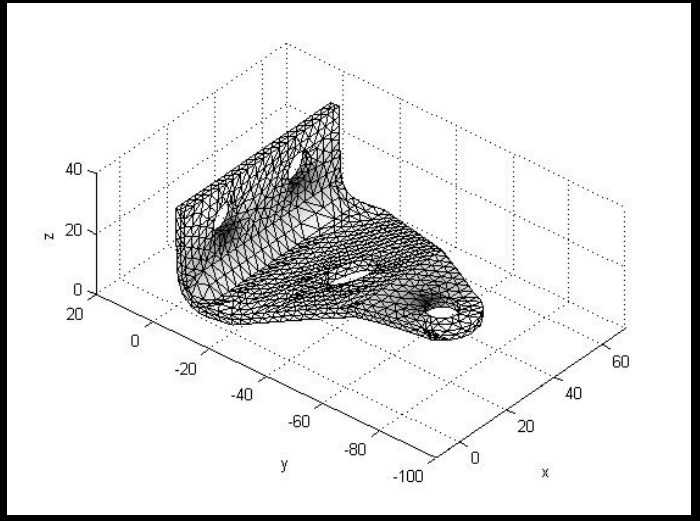
Ack: Brozovsky et al Computers and Structures 85 (2007)

Finite Element Model

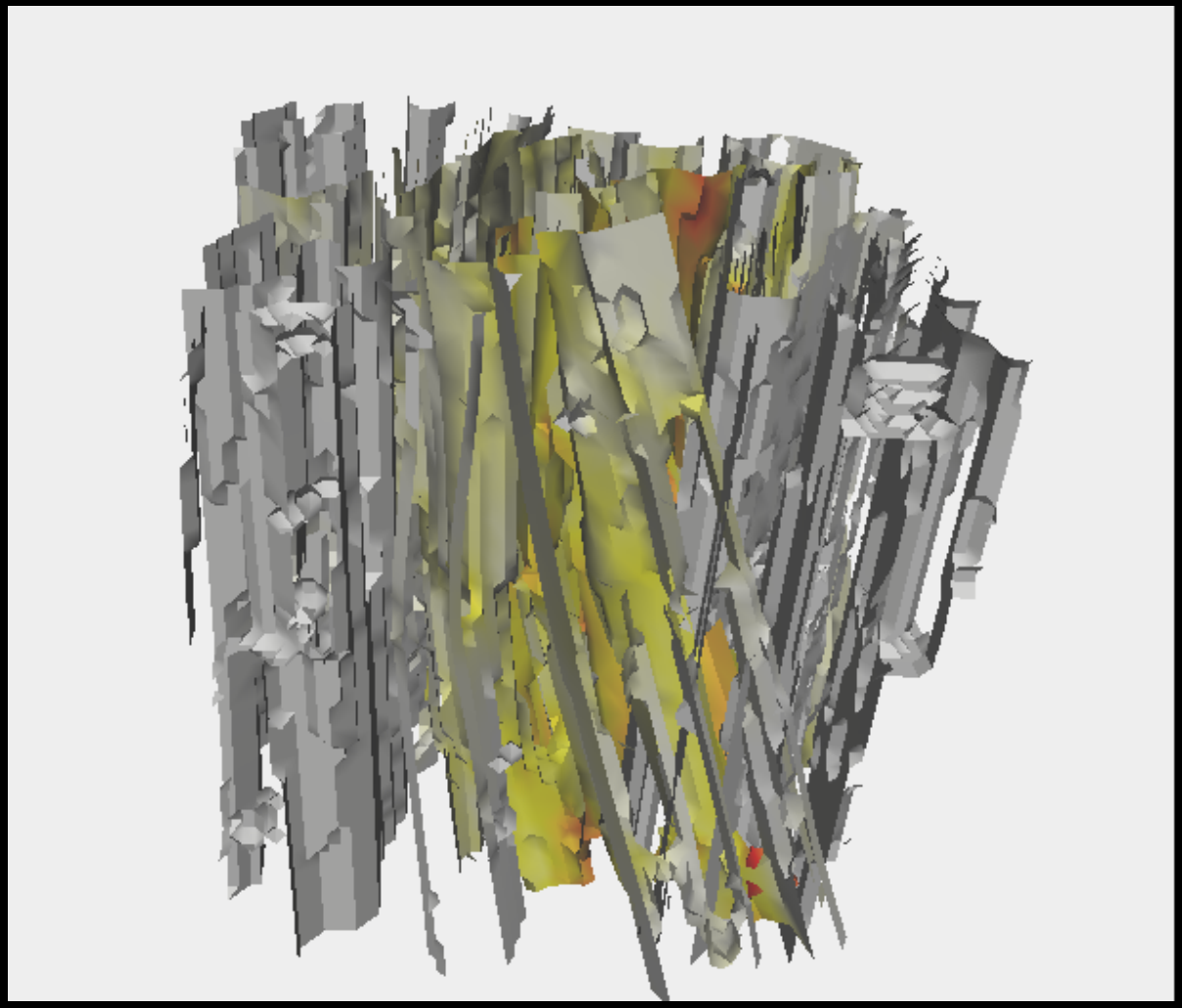
- Elasticity Model
  - Geometry
  - Material properties

$$F = Ku$$

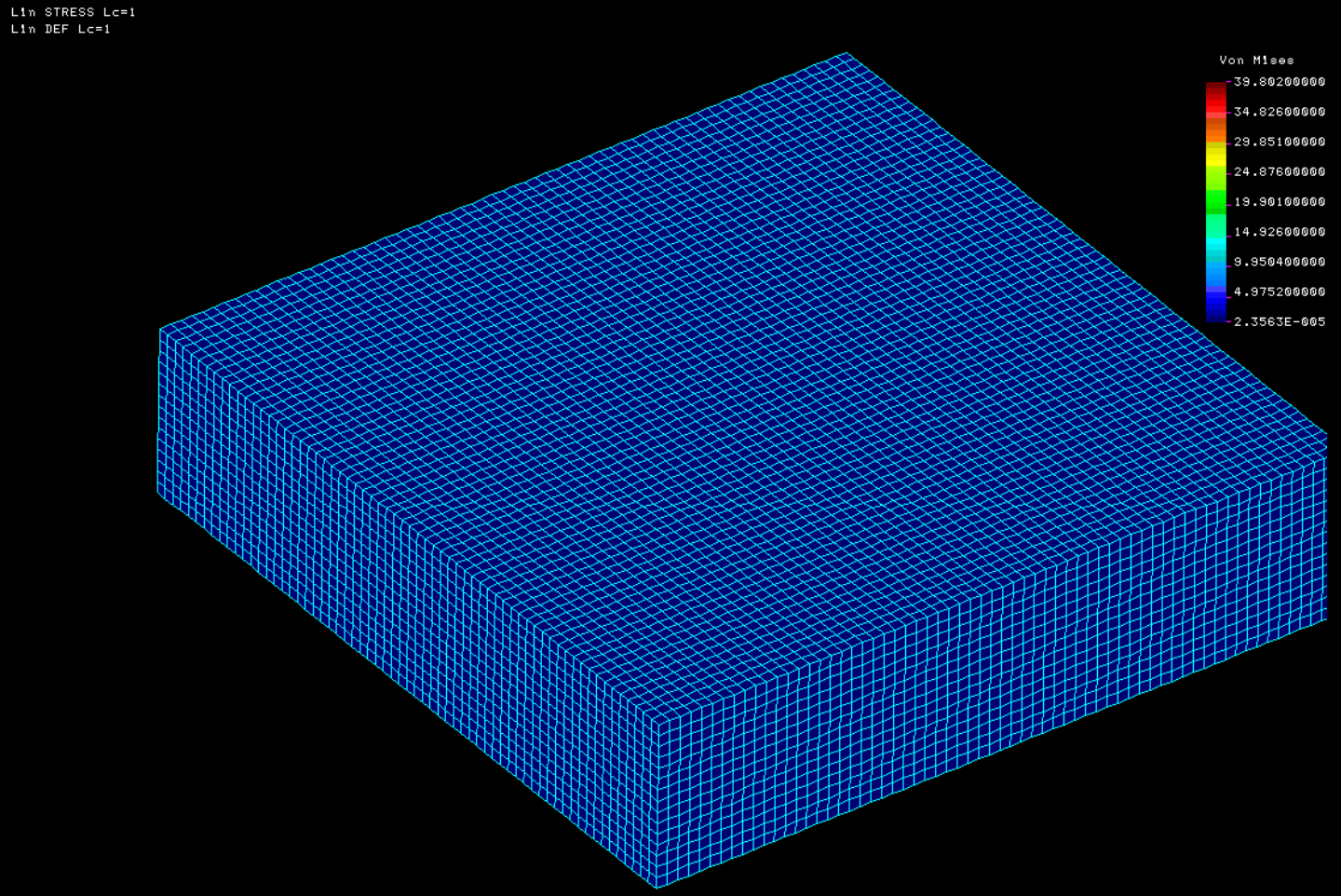
- A better one: Poroelasticity Model?

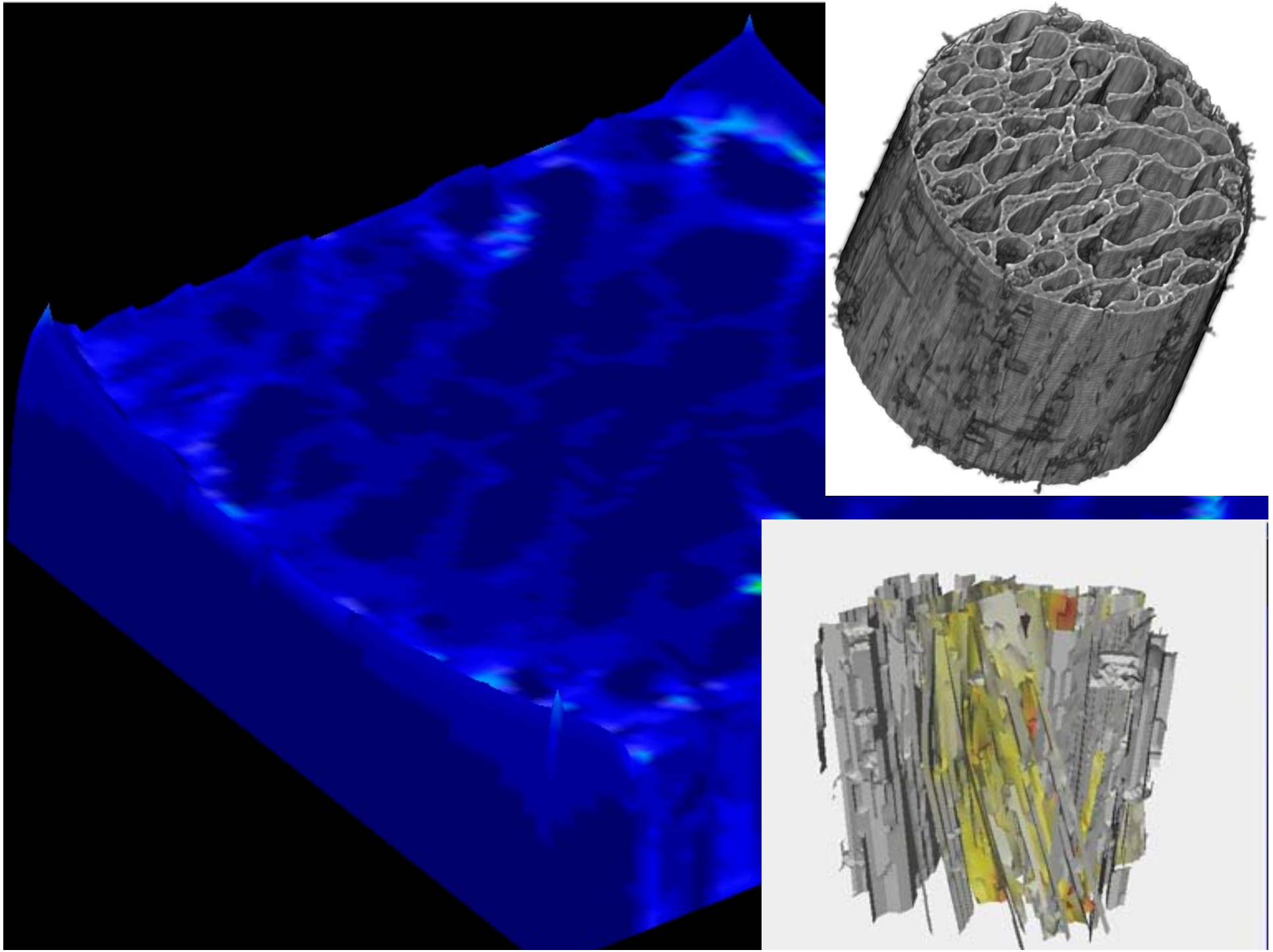


Preliminary Results (1)



Preliminary Results (2)





Discussion and Future Work

- The deformation of trabeculae seems to be along bone's direction
- More data and quantitative analysis
- A descriptor of trabecular bone orietantion
- Better modelling
  - More complicated but detailed meshing
  - More time for FEM
- Validation – real mechanical testing

Acknowledgements

- SSIP 2008 staff
- Dr. A.Bravin, Dr. P.Coan (ID17 ESRF, Grenoble, France) for the data
- Google
- Vienna’s good weather

Thank you