Zurich University of Applied Sciences

School of Engineering

InIT Institute of Applied Information Technology

Visual Computing

Lab & Research Group

Supporting the finite element modelling workflow with MITK Workbench

Thomas Fitze fitz@zhaw.ch

Zurich University of Applied Sciences, Winterthur, Switzerland

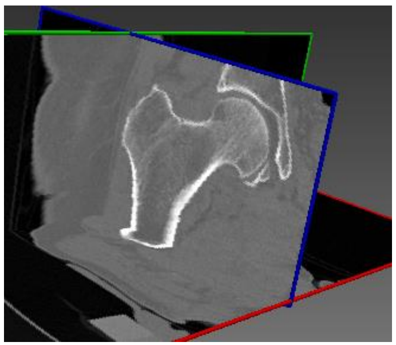
MITK User Meeting 2015, Heidelberg

Content:

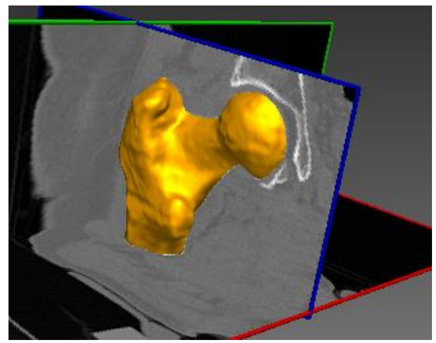
FEM intro – FE workflow improvements with MITK – Results – Retrospection

Finite Element Method (FEM)

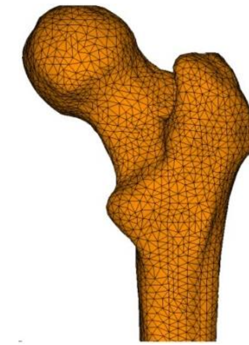
Images
Clinical CT, resolution approximately 0.7-1 mm



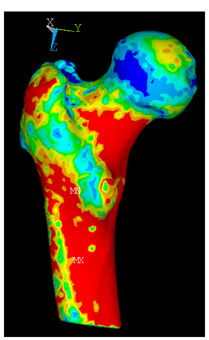
Segmentation
INPUT: DICOM
OUTPUT: STL



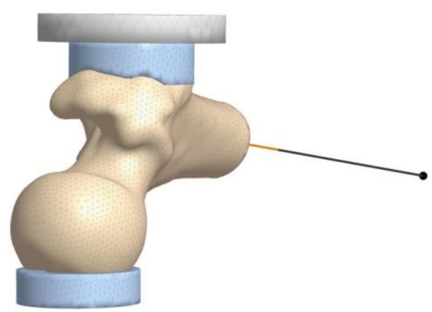
Meshing
INPUT: STL or STEP
OUTPUT: INP



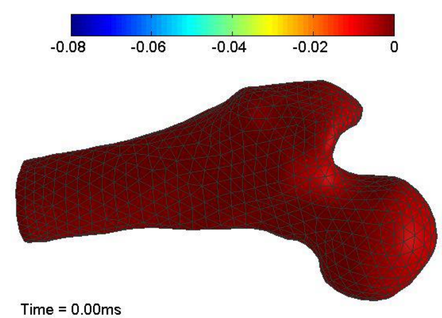
Material mapping
INPUT: INP, DICOM
OUTPUT: Simulation files



Boundary conditions
INPUT: E.g. DIGITIZER DATA
OUTPUT: Simulation input files

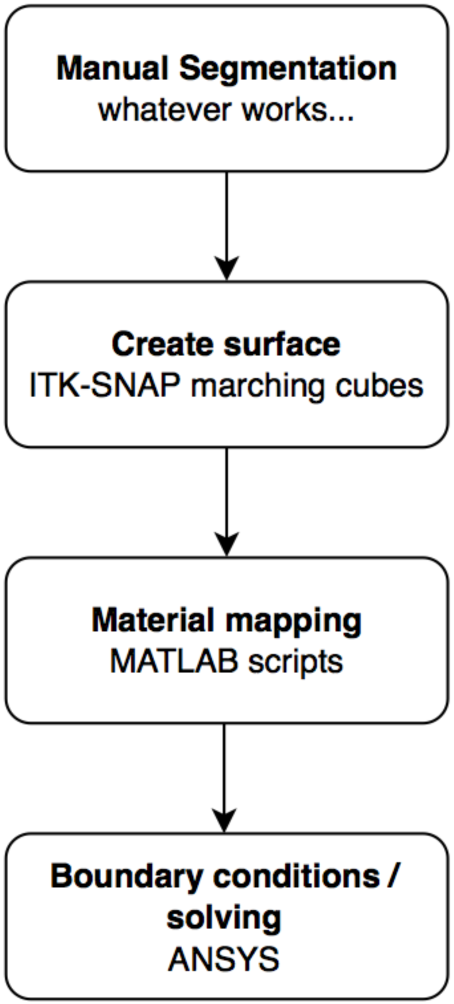


FE Solution
INPUT: SIMULATION INPUT FILES
OUTPUT: TEXT FILES



Traditional FE pipeline

Zurich University
of Applied Sciences
School of Engineering
InIT Institute of Applied
Information Technology



Problems:

- Time consuming segmentation
- Lots of steps in different applications
- User interaction after each step
- Results vary

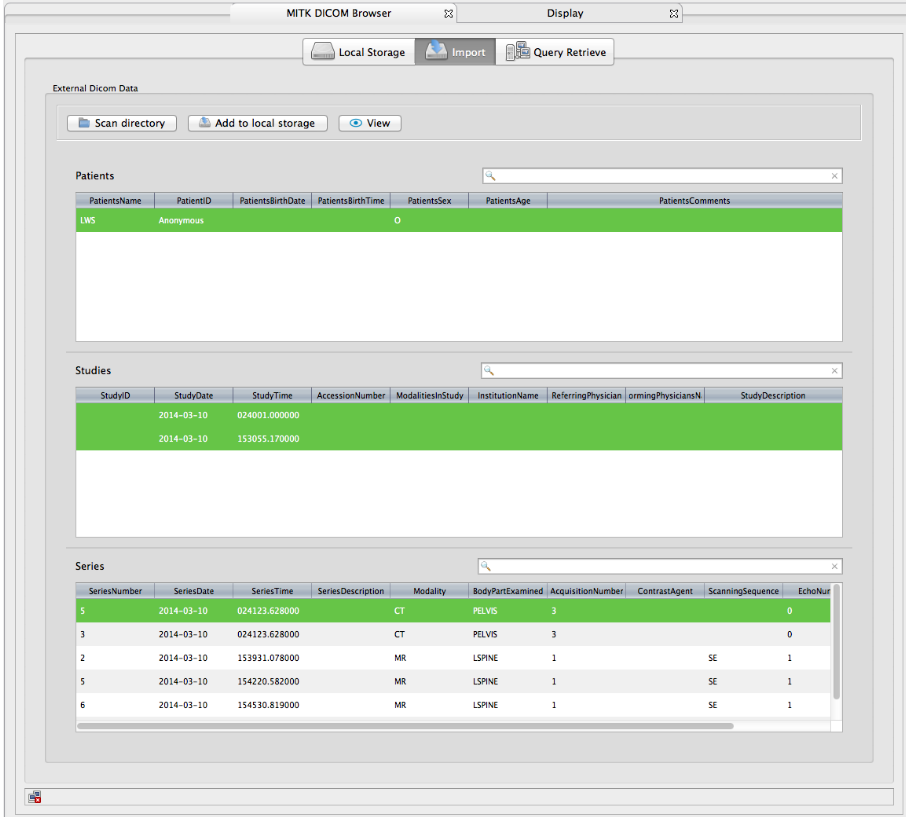
Goals

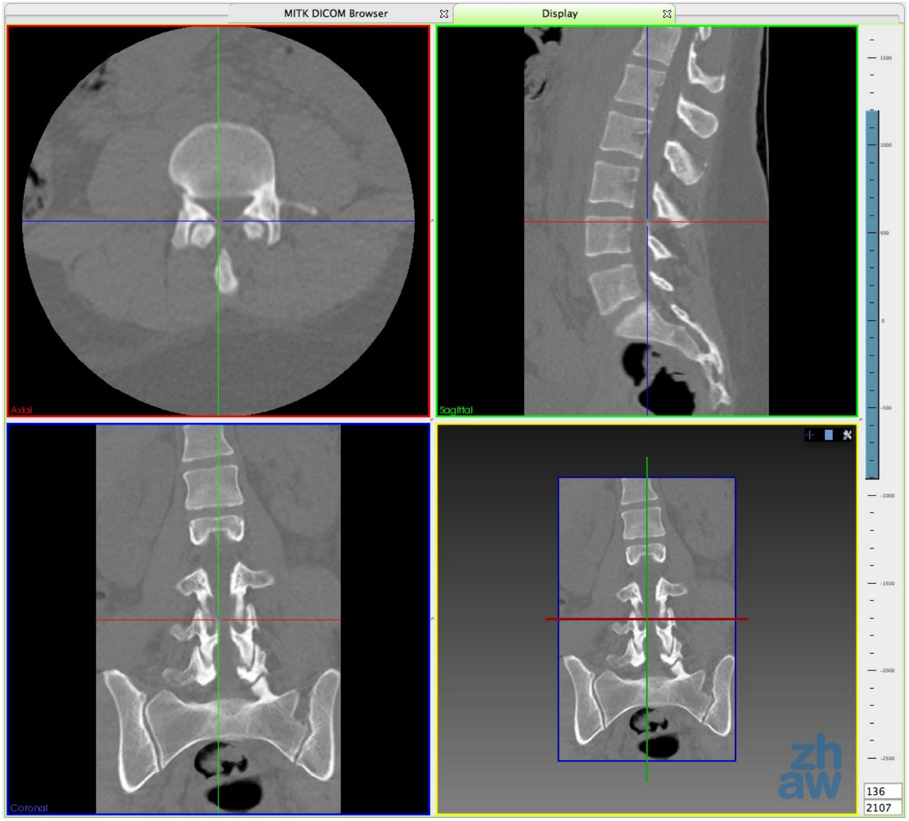
Zurich University
of Applied Sciences
School of Engineering
InIT Institute of Applied
Information Technology

- Integrate all steps into a single application
- Automate the data flow
- Use human input where it counts and reduce interaction time to a minimum
- Speed up segmentation with graph cut

Workflow illustrated (1/4)
Load image

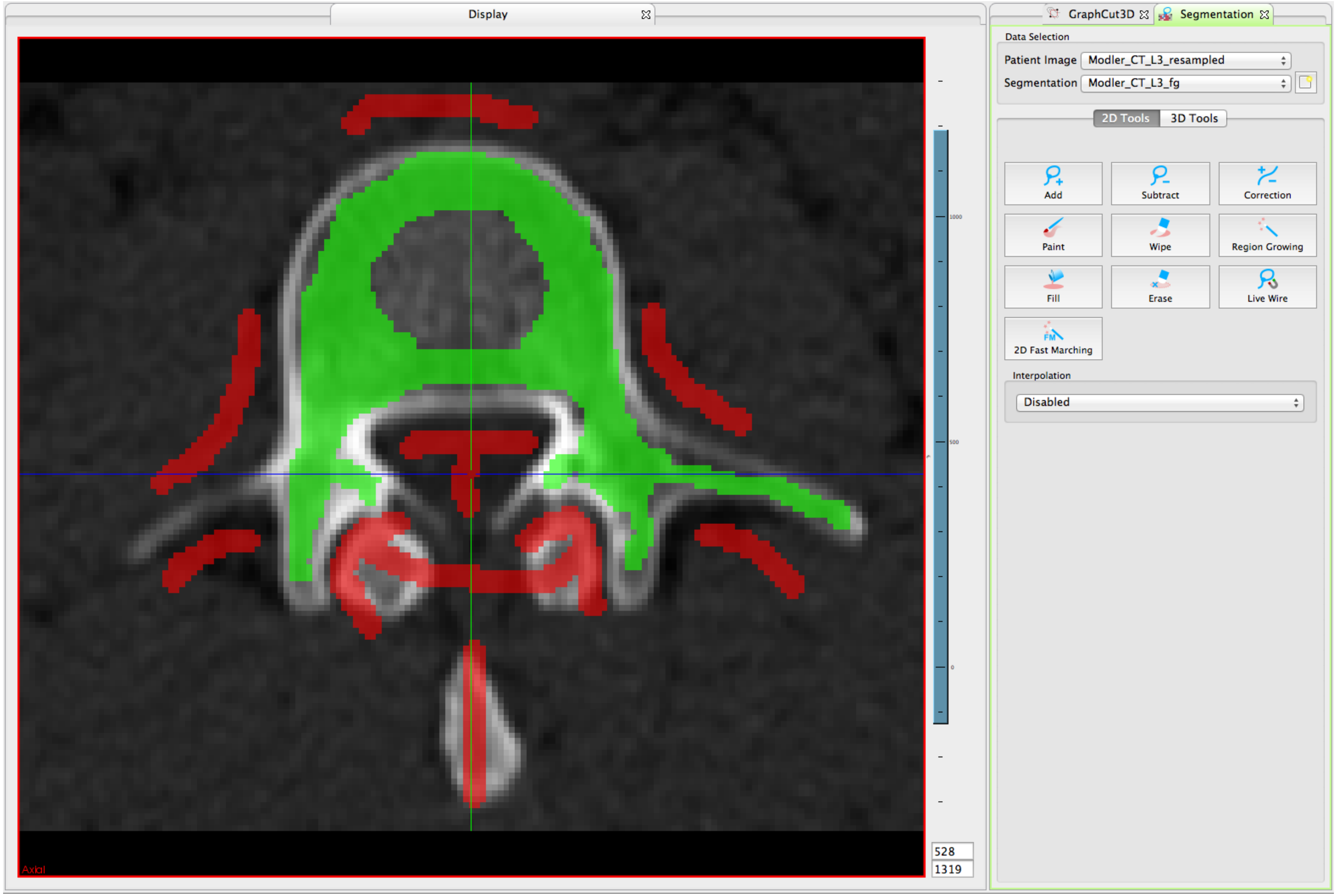
Zurich University
of Applied Sciences
School of Engineering
InIT Institute of Applied
Information Technology





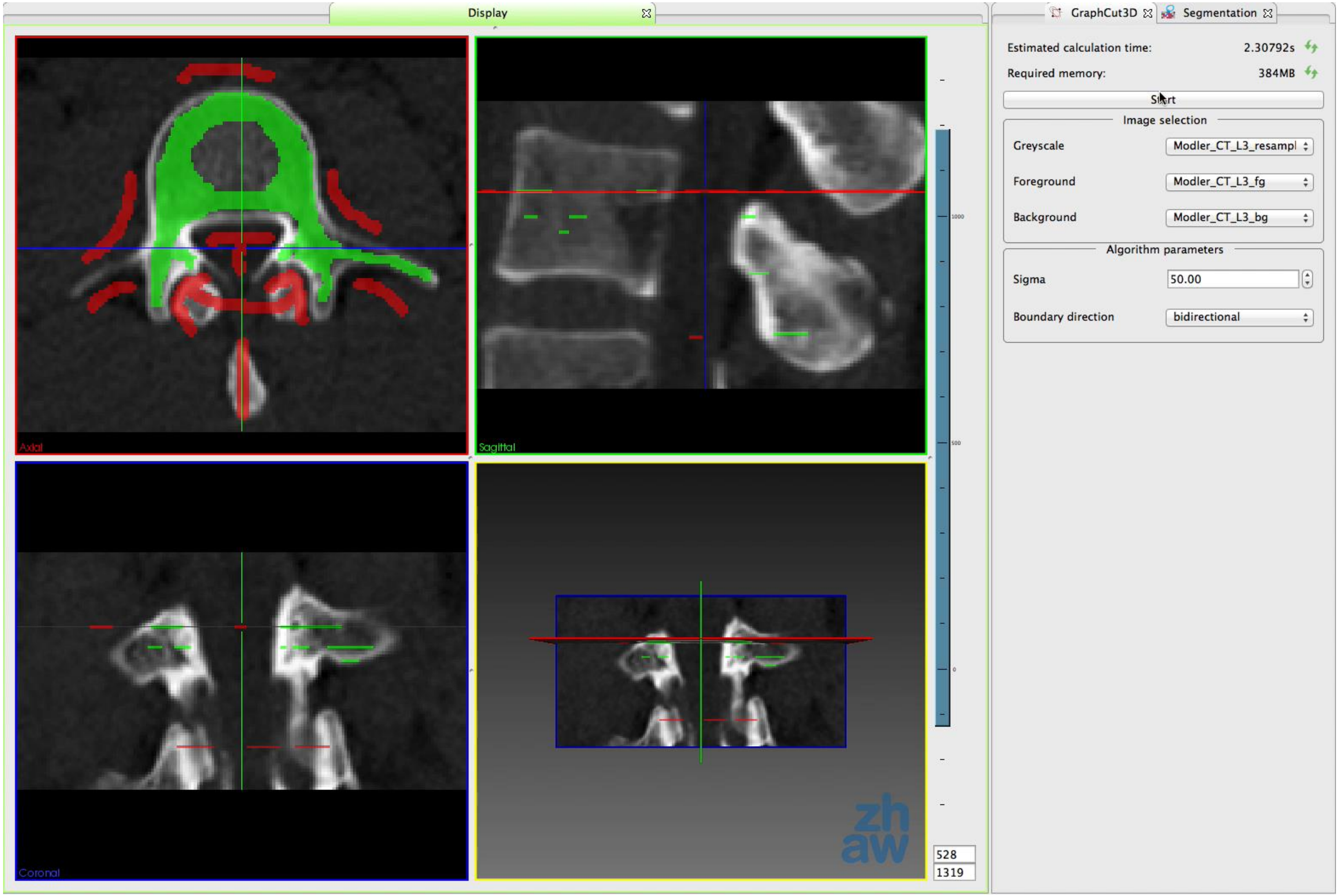
Workflow illustrated (2/4)
Draw foreground and background masks

Zurich University of Applied Sciences
zh aw School of Engineering
InIT Institute of Applied Information Technology



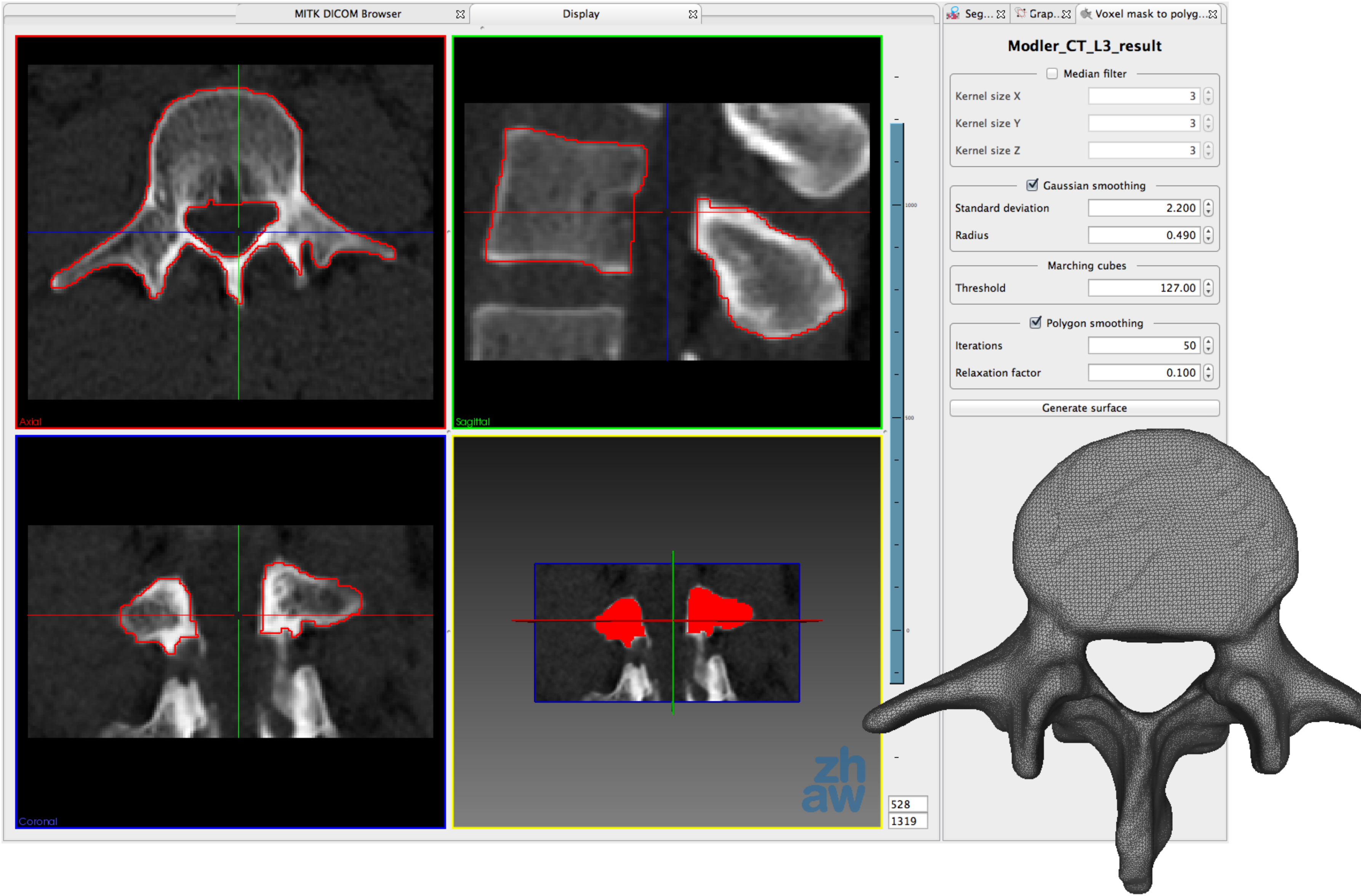
Workflow illustrated (3/4)
Run GraphCut

Zurich University of Applied Sciences
School of Engineering
InIT Institute of Applied Information Technology



Workflow illustrated (4/4)
Generate surface

Zurich University of Applied Sciences
School of Engineering
InIT Institute of Applied Information Technology



Plugins

- Plugins we use from the workbench:
  - DICOM Browser
  - Segmentation Tools
  - Image Cropper
  - Measurement Tools
- Plugins we added
  - 3D Graph cut
  - Image resampler
  - Surface generation
  - Add padding

Summary

Zurich University of Applied Sciences
zh aw School of Engineering
InIT Institute of Applied Information Technology

- Interaction reduced significantly
- Results are comparable to manual segmentation[1]
- Free and open source (GPLv3)
- Currently in use at the Institute for Biomechanics (ETH Zurich) and Institute for Mechanical Systems (ZHAW)
- Available once reviewed or on request: fitz@zhaw.ch

1 Y. Pauchard, T. Fitze, D. Browarnik, A. Eskandari, W. Enns-Bray, H. Pálsson, S. Sigurdsson, Stephen J. Ferguson, Tamara B. Harris, V. Gudnason and B. Helgason. "Interactive Graph-Cut Segmentation for Fast Creation of Finite Element Models from Clinical CT Data for Hip Fracture Prediction." Computer Methods in Biomechanics and Biomedical Engineering, in review.

Feedback

Zurich University
of Applied Sciences
School of Engineering
InIT Institute of Applied
Information Technology

- My personal impressions
- Did I just miss a feature? Let me know!

Feedback (1/3)
Data management

- The data manager is awesome!
- MITK to ITK adaptors are complicated by nature, but:
  - Did you ever call AccessByItk_n with wrong arguments?
    I did…

```
make[6]: *** [Plugins/ch.zhaw.graphcut/CMakeFiles/ch_zhaw_graphcut.dir/src/internal/GraphcutView.cpp.o] Error 1
0 warnings and 16 errors generated.
make[6]: *** [Plugins/ch.zhaw.graphcut/CMakeFiles/ch_zhaw_graphcut.dir/src/internal/ch_zhaw_graphcut_Activator.cpp.o] Error 1
make[5]: *** [Plugins/ch.zhaw.graphcut/CMakeFiles/ch_zhaw_graphcut.dir/all] Error 2
make[4]: *** [all] Error 2
make[3]: *** [CMakeFiles/Workbench-Project-build] Error 2
make[2]: *** [CMakeFiles/Workbench-Project-build.dir/all] Error 2
```

Feedback on MITK (2/3)
Look and feel

- Some inconsistencies:
  - Changing the color property of a binary image via Data Manager will not update the display.
  - Undo in the segmentation tool will not always (but sometimes) trigger a display update.
  - Display property (outline vs. overlay) of binary images changes depending state and does not obey the global setting found under “Preferences”.
  - There’s a global progress bar, but very few plugins use it.

Feedback on MITK (3/3)
Build system and deployment

Zurich University of Applied Sciences
zh aw School of Engineering
InIT Institute of Applied Information Technology

- The Workbench superbuild is very nice and easy to get started!
- A way to enable / disable default plugins on the superbuild level would make it more convenient to setup new developers.
- Deployment of “standalone” plugins to existing MITK Workbenches would be a helpful feature to establish the Workbench as a platform.

Acknowledgements

- Ben Helgason[1] at ETH (FE modelling)
- Yves Pauchard[2] at ZHAW (Graph cut)
- School of Engineering at ZHAW (Funding)

1 Institute for Biomechanics, ETH Zurich, Zurich, Switzerland

2 Visual Computing Lab, Institute of Applied Information Technology, Zurich University of Applied Sciences ZHAW, Winterthur, Switzerland

Q & A

Got anything else? Don’t hesitate to contact me:
Thomas Fitze
fitz@zhaw.ch

Mesh similarity

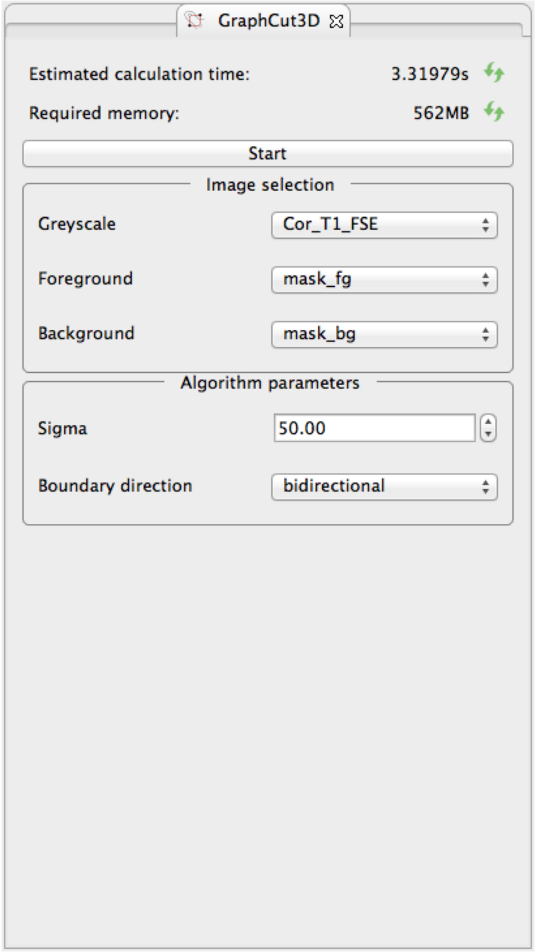
- Dataset N=48 femur segmentations
- Average surface to surface distance 0.21mm
- Absolute maximal difference (Hausdorff distance) 3.75mm +- 1.26mm
- Mean overlap (Dice coefficient) 0.973 +- 0.005

Graph cut algorithm

Zurich University of Applied Sciences
zh aw School of Engineering
InIT Institute of Applied Information Technology

- Minimize energy function composed of **regional**, **boundary** and **hard** constraints
- Graph contains Source (=object) and Terminal (=background) nodes, plus on node for each voxel
- Edge weights encode energy function
- Finds the global minimum using discrete optimization (max flow / min cut)

MITK Graph Cut 3D Plugin



- Implemented as ITK filter
- Uses V. Kolmogorovs implementation of the maxflow algorithm[1]
- Memory intensive
  - ~28GB on an 512^3 image
- Thrashing is a huge issue

1. Y. Boykov, V. Kolmogorov. "An Experimental Comparison of Min-Cut/Max-Flow Algorithms for Energy Minimization in Computer Vision." IEEE Transactions on Pattern Analysis and Machine Intelligence, September 2004

Workflow with MITK Workbench

Zurich University of Applied Sciences
School of Engineering
InIT Institute of Applied Information Technology