

Supporting the finite element modelling workflow with MITK Workbench

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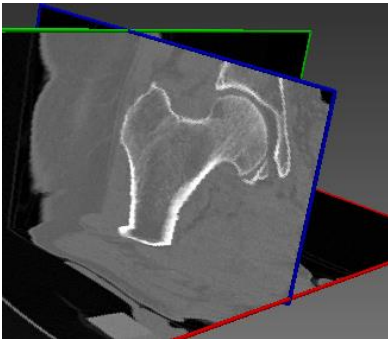
Content:

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

Finite Element Method (FEM)

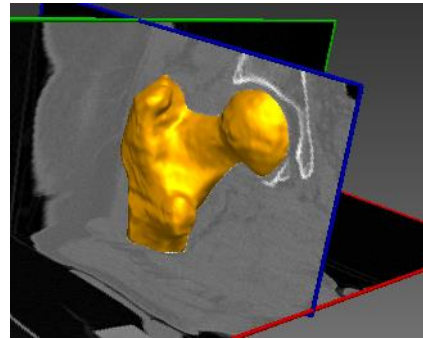
Images

Clinical CT, resolution
approximately 0.7-1 mm



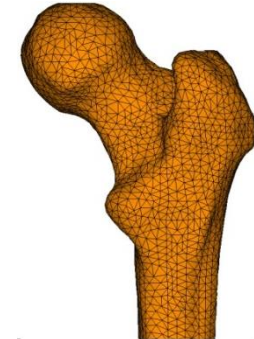
Segmentation

INPUT: DICOM
OUTPUT: STL



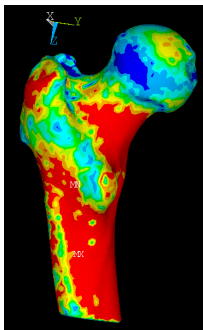
Meshing

INPUT: STL or STEP
OUTPUT: INP



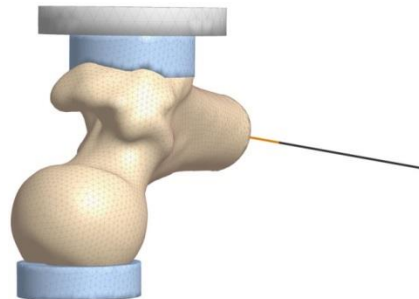
Material mapping

INPUT: INP, DICOM
OUTPUT: Simulation files



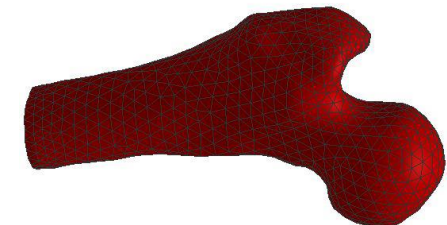
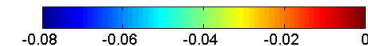
Boundary conditions

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



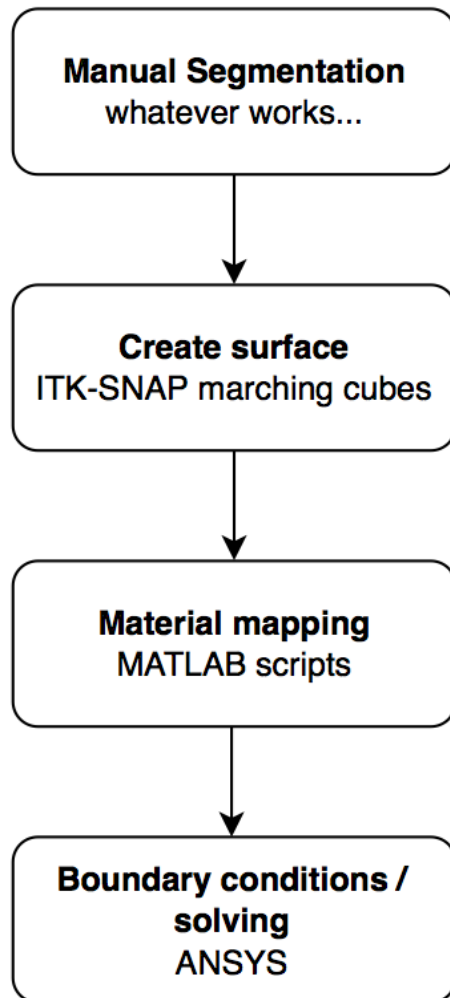
FE Solution

INPUT: SIMULATION INPUT FILES
OUTPUT: TEXT FILES



Time = 0.00ms

Traditional FE pipeline



Problems:

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

Goals

- 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

MITK DICOM Browser Display

Local Storage Import Query Retrieve

External Dicom Data

Scan directory Add to local storage View

Patients

PatientsName	PatientID	PatientsBirthDate	PatientsBirthTime	PatientsSex	PatientsAge	PatientsComments
LWS	Anonymous				0	

Studies

StudyID	StudyDate	StudyTime	AccessionNumber	ModalitiesInStudy	InstitutionName	ReferringPhysician	ormingPhysiciansN	StudyDescription
	2014-03-10	024123.628000						
	2014-03-10	153055.170000						

Series

SeriesNumber	SeriesDate	SeriesTime	SeriesDescription	Modality	BodyPartExamined	AcquisitionNumber	ContrastAgent	ScanningSequence	EchoNum
5	2014-03-10	024123.628000		CT	PELVIS	3			0
3	2014-03-10	024123.628000		CT	PELVIS	3			0
2	2014-03-10	153931.078000		MR	LSPINE	1	SE		1
5	2014-03-10	154220.582000		MR	LSPINE	1	SE		1
6	2014-03-10	154530.819000		MR	LSPINE	1	SE		1

MITK DICOM Browser Display

Axial Sagittal

Coronal

zhaw

136
2107

Workflow illustrated (2/4)

Draw foreground and background masks

The screenshot displays a software interface for medical image segmentation. The main window, titled "Display", shows an axial CT scan of a skull. A green mask highlights the brain tissue, and red masks highlight the skull and other structures. A vertical green line and a horizontal blue line are overlaid on the image. To the right of the image is a vertical color scale bar with numerical markers at 0, 500, and 1000. At the bottom left of the image, the word "Axial" is written. At the bottom right, there are two small boxes containing the numbers "528" and "1319".

The right-hand side of the interface is a control panel titled "Segmentation". It includes a "Data Selection" section with dropdown menus for "Patient Image" (set to "Modler_CT_L3_resampled") and "Segmentation" (set to "Modler_CT_L3_fg"). Below this are two tabs: "2D Tools" and "3D Tools". The "2D Tools" section contains several icons for "Add", "Subtract", "Correction", "Paint", "Wipe", "Region Growing", "Fill", "Erase", and "Live Wire". There is also a "2D Fast Marching" section with a "FM" icon. At the bottom of the control panel is an "Interpolation" section with a dropdown menu set to "Disabled".

Workflow illustrated (3/4)

Run GraphCut

The screenshot displays the GraphCut3D software interface. The main window is titled "Display" and shows four views of a segmented vertebra: Axial, Sagittal, Coronal, and a zoomed-in Sagittal view. The segmentation results are shown in green for the foreground and red for the background. The right sidebar contains configuration options for image selection and algorithm parameters.

GraphCut3D Segmentation

Estimated calculation time: 2.30792s
Required memory: 384MB

Start

Image selection

Greyscale: Modler_CT_L3_resampl
Foreground: Modler_CT_L3_fg
Background: Modler_CT_L3_bg

Algorithm parameters

Sigma: 50.00
Boundary direction: bidirectional

528
1319

Workflow illustrated (4/4)

Generate surface

The screenshot displays the MITK DICOM Browser interface for generating a surface from a CT scan. The main window is divided into four viewports: Axial (top-left), Sagittal (top-right), Coronal (bottom-left), and a zoomed-in view (bottom-right). The zoomed-in view shows the segmented vertebra in red. The parameter control panel on the right, titled 'Modler_CT_L3_result', includes the following settings:

- Median filter
- Kernel size X: 3
- Kernel size Y: 3
- Kernel size Z: 3
- Gaussian smoothing
- Standard deviation: 2.200
- Radius: 0.490
- Marching cubes
- Threshold: 127.00
- Polygon smoothing
- Iterations: 50
- Relaxation factor: 0.100

A 'Generate surface' button is located at the bottom of the parameter panel. The 3D mesh model of the vertebra is shown in the bottom right corner. The MITK logo is visible in the bottom right corner of the interface.

528
1319

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

- Interaction reduced significantly
- Results are comparable to manual segmentation¹
- 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

- 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...

```
1614 make[6]: *** [Plugins/ch.zhaw.graphcut/CMakeFiles/ch_zhaw_graphcut.dir/src/  
internal/GraphcutView.cpp.o] Error 1  
1615 0 warnings and 16 errors generated.  
1616 make[6]: *** [Plugins/ch.zhaw.graphcut/CMakeFiles/ch_zhaw_graphcut.dir/src/  
internal/ch_zhaw_graphcut_Activator.cpp.o] Error 1  
1617 make[5]: *** [Plugins/ch.zhaw.graphcut/CMakeFiles/ch_zhaw_graphcut.dir/all]  
Error 2  
1618 make[4]: *** [all] Error 2  
1619 make[3]: *** [CMakeFiles/Workbench-Project-build] Error 2  
1620 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

- 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 Helgason¹ at ETH (FE modelling)
- Yves Pauchard² 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:

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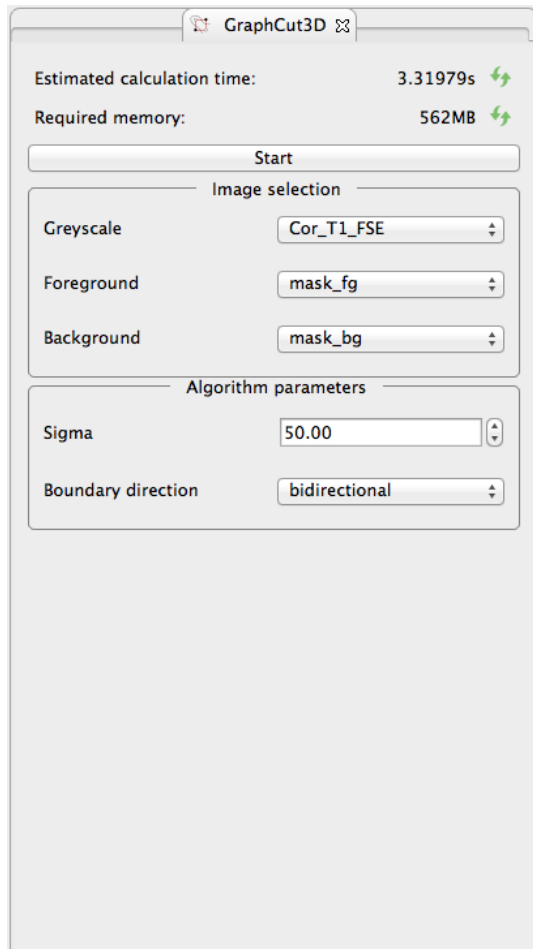
Mesh similarity

- 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

- Minimize energy function composed of **regional**, **boundary** and **hard** constraints
- Graph contains Source (=object) and Terminal (=background) nodes, plus one 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. Kolmogorov's implementation of the maxflow algorithm¹
- Memory intensive
 - ~28GB on an 512³ 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

