

Robust Surface Reconstruction using IR-Laser-Pointer

SEP Final Presentation

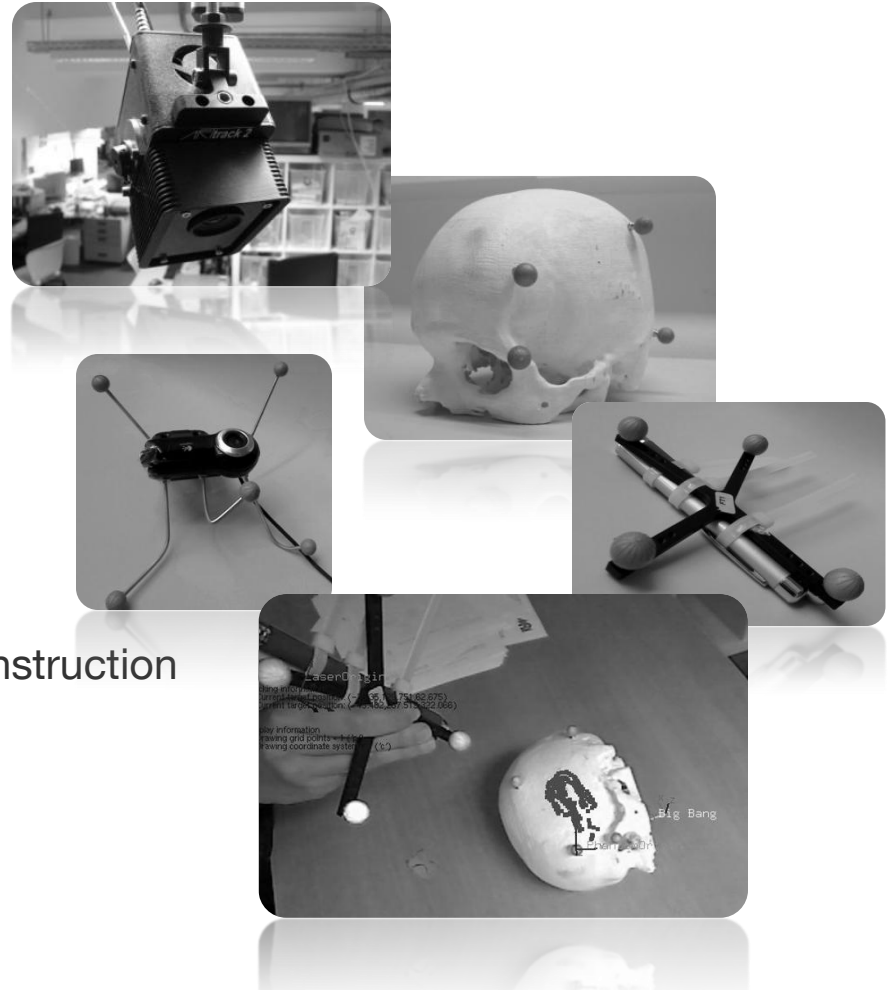
Aslı Okur

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Outline

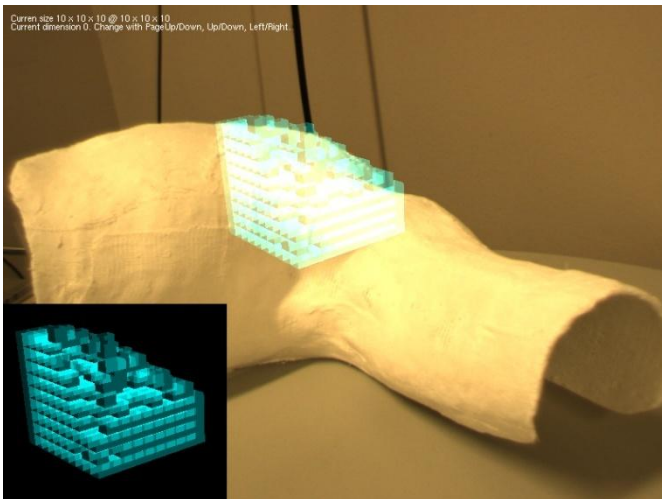
- Motivation
 - Why surface reconstruction?
 - Why laser pointer?
- System
 - Overview
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- Solution
 - Elimination of Outliers
 - Gridding and Averaging
 - Interpolation for denser surface reconstruction
- Evaluation
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Motivation

Why surface reconstruction?

- Real question: Why surface reconstruction at the functional imaging group?
- Need for surface in functional surface imaging systems:
 - Beta probe → „positron emission surface imaging“
 - Optical probe → „hyperspectral surface imaging“

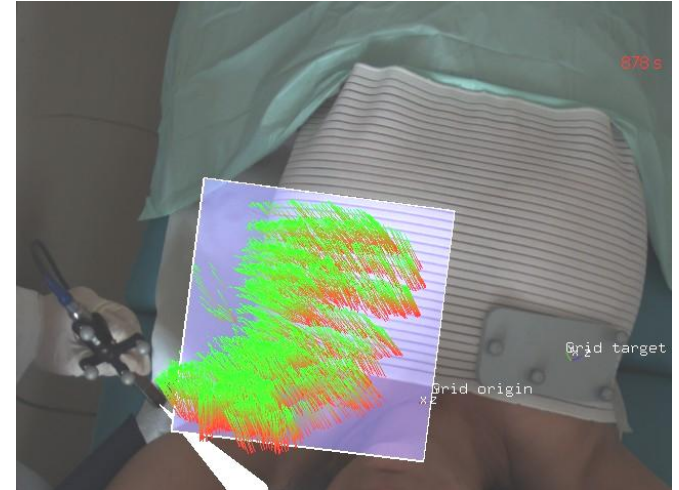
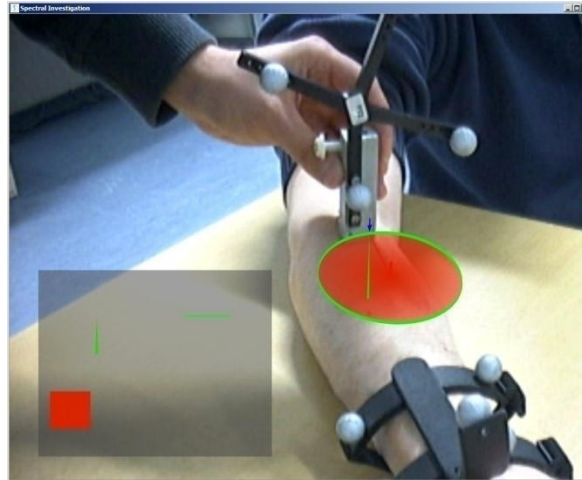
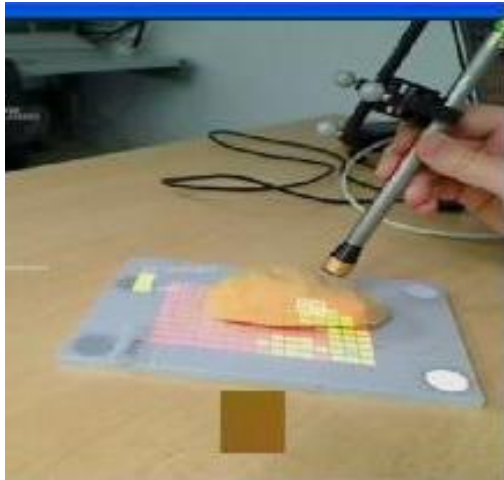


- Need for a priori information of surface in tomographic imaging systems:
 - Gamma probe → „freehand single photon emission tomography“



Why laser pointer?

- Integrated / simultaneous acquisition
 - Optical-, Beta or Gamma Probe + Surface
 - Cheap
 - Non contact
 - Fast

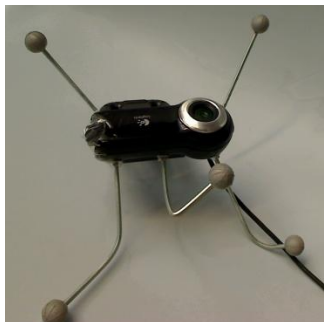


System

Overview

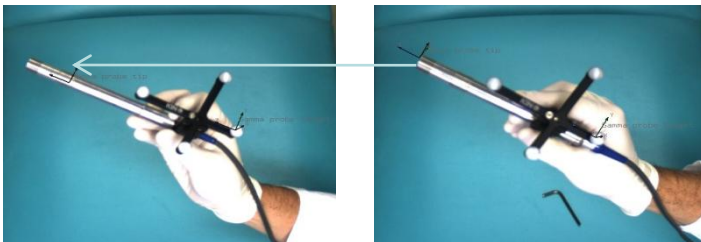
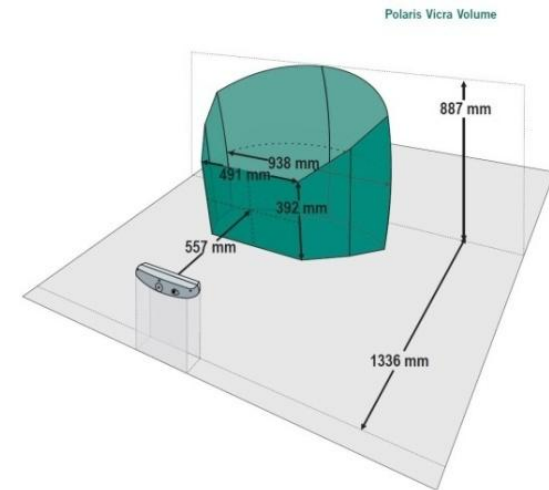
The laser surface reconstruction system consist of:

- Optical 3D tracker
- IR-laser-pointer (calibrated)
- Visible laser-pointer
- Webcam with markers (calibrated)
- Optical markers
- PC with CAMPAR



Problems

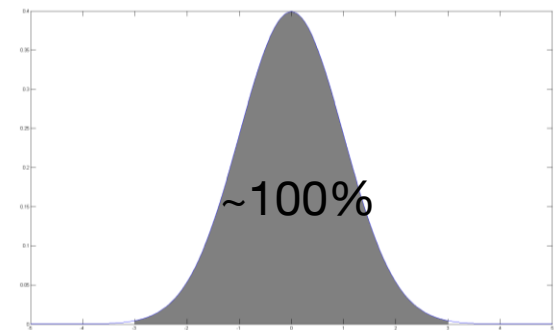
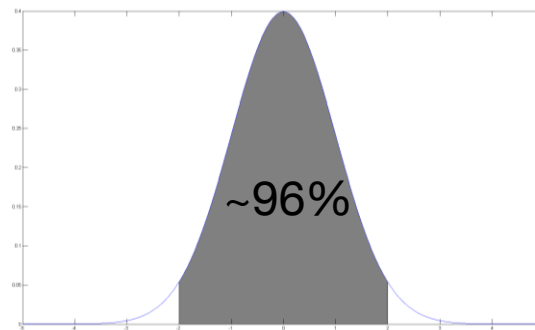
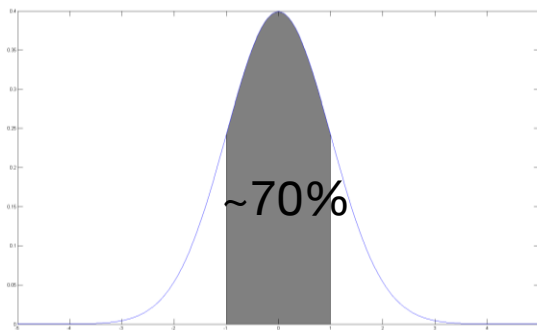
- Scattered points
 - No grid
 - Density inhomogeneity
- Reflections
- Freehand nature
- Tracking errors
 - Undeclared tracking targets
 - Undeclared tracking balls
 - Calibration mistakes
 - Objects out of sight



Solution

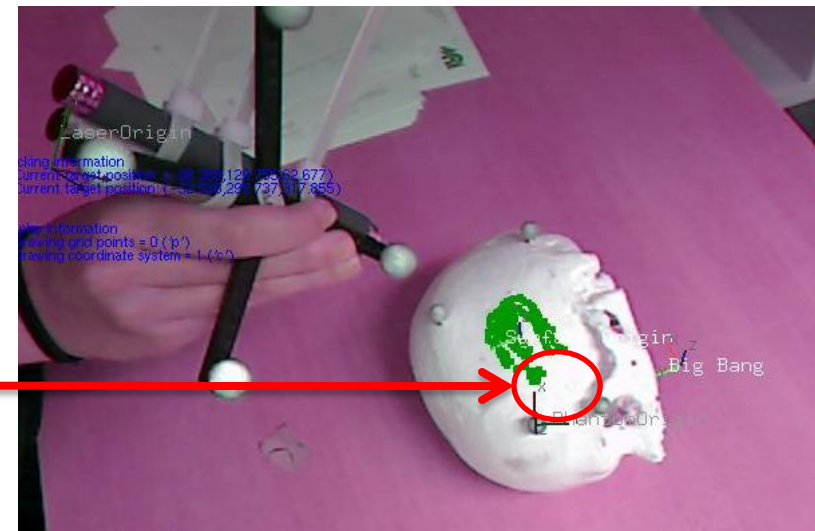
Elimination of Outliers

- From ART Coordinates to “Surface” Coordinates
 - Principal Component Analysis / SVD
 - Idea: Smallest variance should be the z-axis
 - surfaces where $z=f(x,y)$
- Sigma factor – sigma values from SVD
 - Idea: Thresholding using sigma (standard deviation)
 - Gaussian distribution → 2 sigma approx. 95.6 % of all points



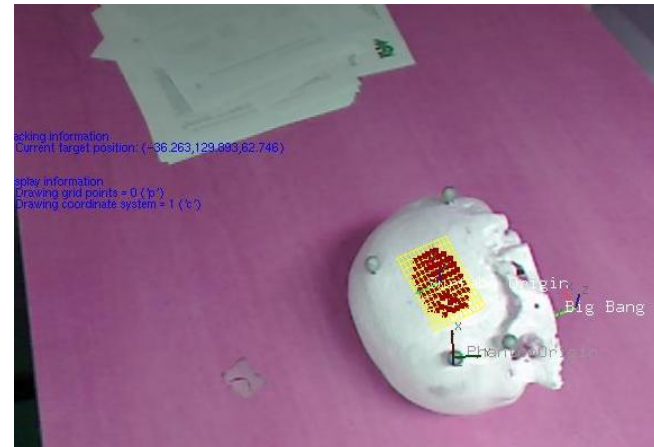
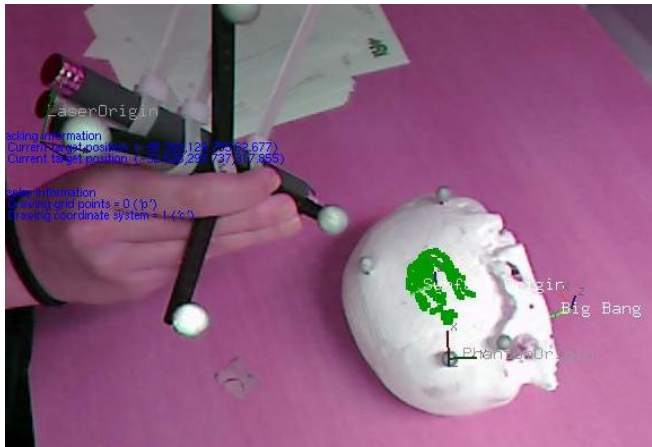
Elimination of Outliers

- Correction of surface coordinates using SVD with points after elimination
 - Good points far away do not help us
- User control
 - Best parameters are not the same for different datasets



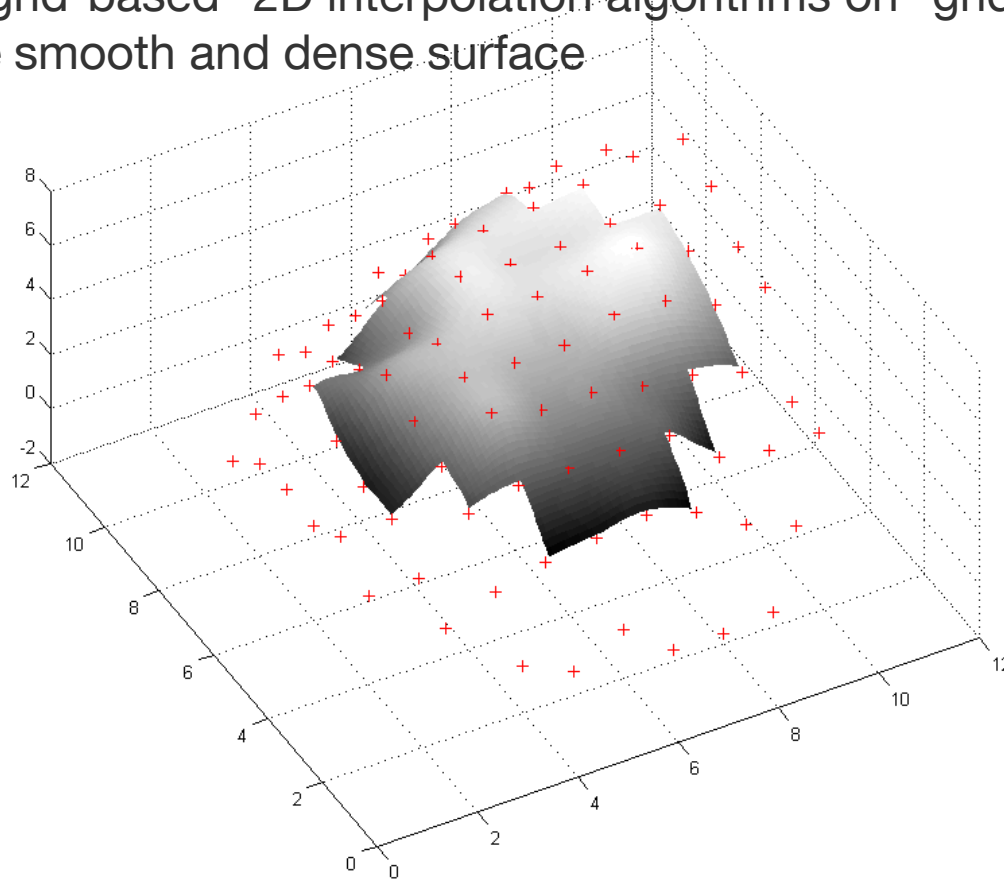
Gridding and Averaging

- Merging close points (filtering)
 - Parameters
 - Gridfactor
 - Sigmafactor
- Interpolation (filling holes)
 - Nearest neighbor interpolation → easy, alternative delaunay
 - Area of interest → ellipse around the surface center (~ elliptical grid)



Interpolation for denser surface reconstruction

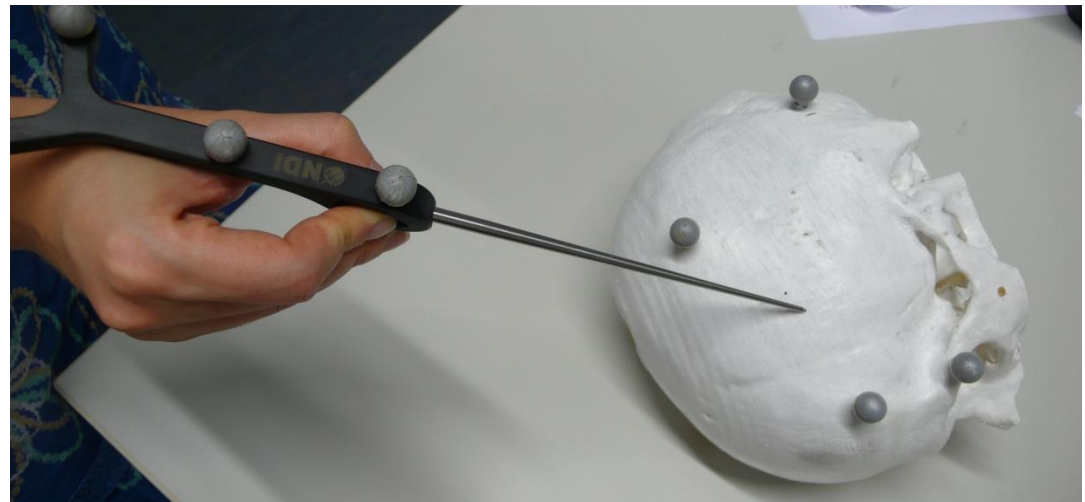
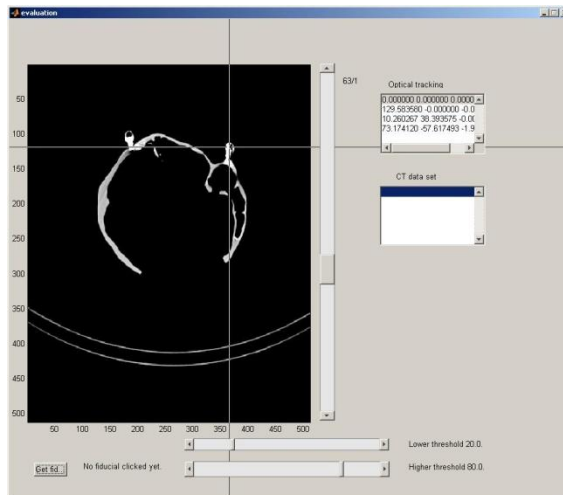
- Use of “grid-based” 2D interpolation algorithms on “gridded” data in order to generate smooth and dense surface



Evaluation

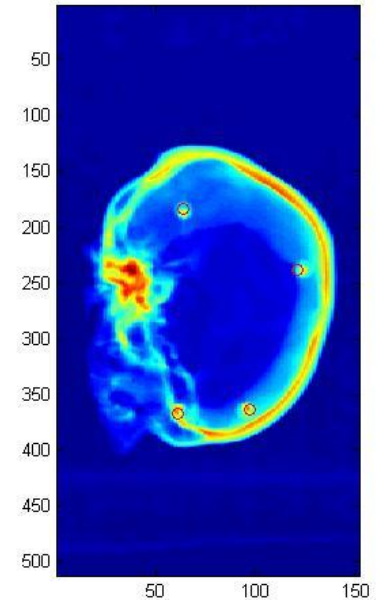
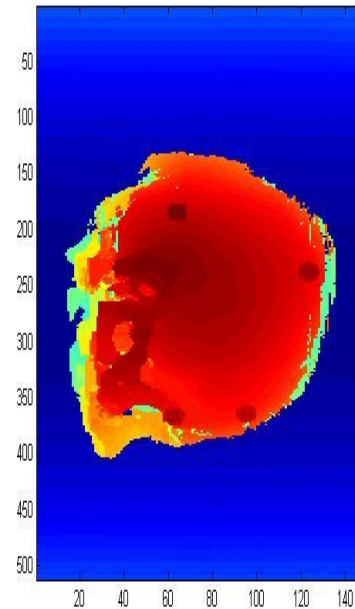
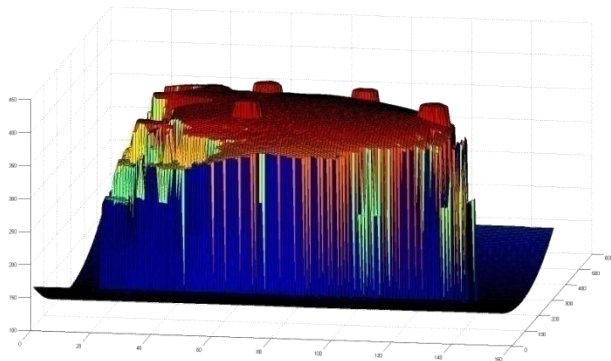
Testing

- Object to scan with optical markers
 - CT scan for exact surface
 - NDI Pointer freehand scan (as reference)
 - Laser Pointer freehand scan
- Calculation of the transformation from Optical to CT coordinates using point based registration and interactive segmentation of markers



Testing

- Surface extraction from CT using threshold on gradient
- Interpolation of CT surface for positions scanned with pointers
- Calculation of errors using different parameters:
 - Grid size
 - Sigma factor
 - Segmentation threshold for CT
 - Interpolation algorithm
 - Similarity measure



Results

	Grid factor						
	3	4	5	6	7	8	raw
Laser Points	5.622390	6.841038	7.545981	7.142745	7.174150	7.137274	9.329420
# Points	16	32	60	88	124	172	248
NDI Points	2.177786	2.346541	2.609317	2.649374	2.709613	2.772960	2.509174
# Points	16	32	60	88	124	172	222

Fix parameters:

- Dissimilarity: SSD
- Interpolation type: spline
- Threshold: 160
- Sigma factor: 2.5

Grid size: ~36.2x20.5 mm

Voxel size: Grid size / Grid factor

Points = # Points calculated
and displayed

Results

	Sigma factor						
	1.5	2	2.5	3	3.5	4	raw
Laser Points	2.209249	5.045702	7.142745	7.636015	8.719450	8.719450	9.329420
# Points	123	197	225	236	248	248	248
NDI Points	2.624360	2.488118	2.649374	3.101513	3.142340	3.174462	2.509174
# Points	66	149	182	202	213	215	222

Fix parameters:

- Dissimilarity: SSD
- Interpolation type: spline
- Threshold: 160
- Grid factor: 6

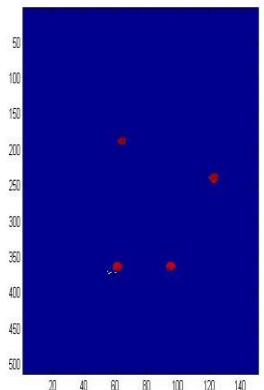
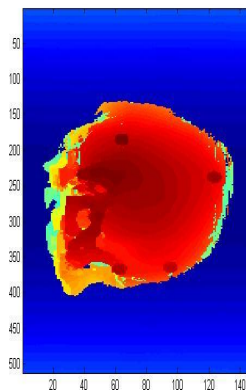
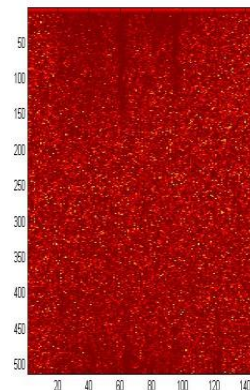
Points = # Points left after SVD

Results

	Threshold							
	5	40	80	120	160	200	240	800
NDI	110.594	2.45892	2.58305	2.70051	2.50917	2.62183	2.70234	398.592
calculated	106.814	2.22781	2.41400	2.54029	2.64937	2.71695	2.77887	402.378
Laser	106.066	9.04427	9.15659	9.25242	9.32942	9.38582	9.47230	403.021
calculated	106.183	6.82083	7.01023	7.10240	7.14274	7.22239	7.30927	402.932

Fix parameters:

- Dissimilarity: SSD
- Interpolation type: spline
- Sigmafactor: 2.5
- Gridfactor: 6



Results

	Dissimilarity		
	SSD	SAD	NCC
NDI	2.509174	2.174724	0.988684
calculated	2.649374	2.255506	0.970732
Laser	9.329420	5.663289	0.402029
calculated	7.142745	4.671462	0.398337
Laser 2	5.938651	3.232337	0.675796
calculated	3.219852	2.631725	0.956558

- Interpolation type: spline
- Threshold: 160
- Sigma factor: 2.5
- Grid factor: 6

Conclusion & Outlook

Conclusions

- Simple approach for „gridding“ of non-uniform, inhomogen density scattered points
- Simple approach for filtering out outliers
- Considerable user dependence on results and acquisitions
- Still place for improvement (comparison with NDI pointer)

Work in progress / future work

- Delaunay triangulation for “filling holes” (almost finished)
- Interpolation implementation / inclusion of current interpolation algorithms into CAMPAR
- Inclusion into functional probe applications
- Mechanical integration of pointer and probes
- Thorough evaluation

**Thank you
for your attention**