Improving the MEG-MRT-Co-Registration

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Abstract

Magnetoencephalography (MEG) allows a non-invasive reconstruction of cerebral activity. It can be used as a clinical tool for pre-surgical diagnosis. Head-models are developed from magnetic resonance imaging (MRI) data and used for MEG source analysis and the detected cortical activity centers are projected to MRI data. These procedures need an MEG-MRI co-registration. This is always subject to errors. Additional surface points were obtained using a 3D digitizer (3Space FASTRAK©, Polhemus Incorporated, Colchester, Vermont U.S.A.). In our work, using an ICP algorithm to these surface points, we show that the accuracy of the matching of MEG and MRI data can be improved when compared with the current standard.

Method

- Create surface segmentation from MRI images.
- Record surface points with Polhemus FASTRAK© digitizer.
- ***(1)*** Manually set fiducials on the segmented MRI surface and align the recorded point clouds.
- ***(2)*** Align recorded point clouds using iterative closest point (**ICP**) algorithm.
- ***(3)*** Align recorded point clouds using fiducial weighted iterative closest point (**fwICP**) algorithm.
- For every point cloud: compare the mean distance to the segmented MRI surface for the different registration methods (1-3).

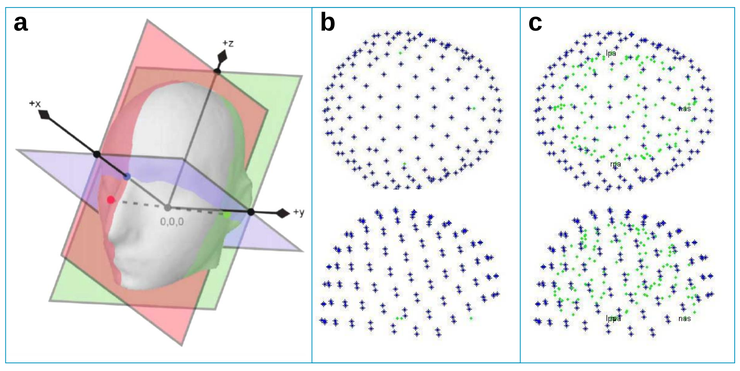

Figure 1: MEG-head-coordinate-system.
a: The origin is located in the middle of LPA (green) and RPA (red), the X-axis points towards NAS (blue), the Y-axis is orthogonal to X (approximately towards LPA) and is placed on the plane spanned by the three fiducials, the Z-axis and is orthogonal to X and Y.
b: Currently represented data in the MEG-head-coordinate system. The positions of the MEG-sensors (blue) and the three fiducials (green).
c: Shows the additional surface points (green) represented in the MEG-head-coordinate system.

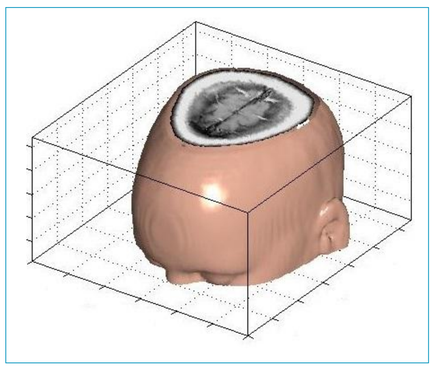

Figure 2: MRI-coordinate system.
3D volumetric representation of the data with voxels. The MRI-coordinate system does not specify the physical dimensions or how the heads relates to the voxels indices. Surface reconstruction is performed from the MRI-data, which is represented in the MRI-coordinate system.

Results

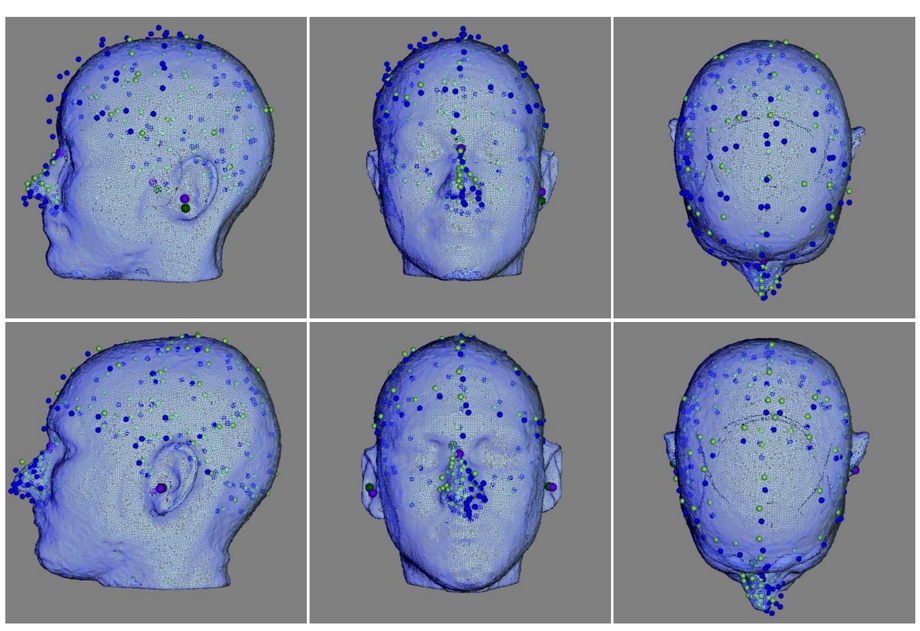

Figure 3: Registration of recorded surface points to a segmented MRI surface. Comparing a manual registration with a registration performed by the ICP algorithm.
Blue/purple: Manual registration. fiducials are shown in purple, other points in blue.
Light/dark green: Registration with ICP algorithm. fiducials are shown in dark green, other points in light green.

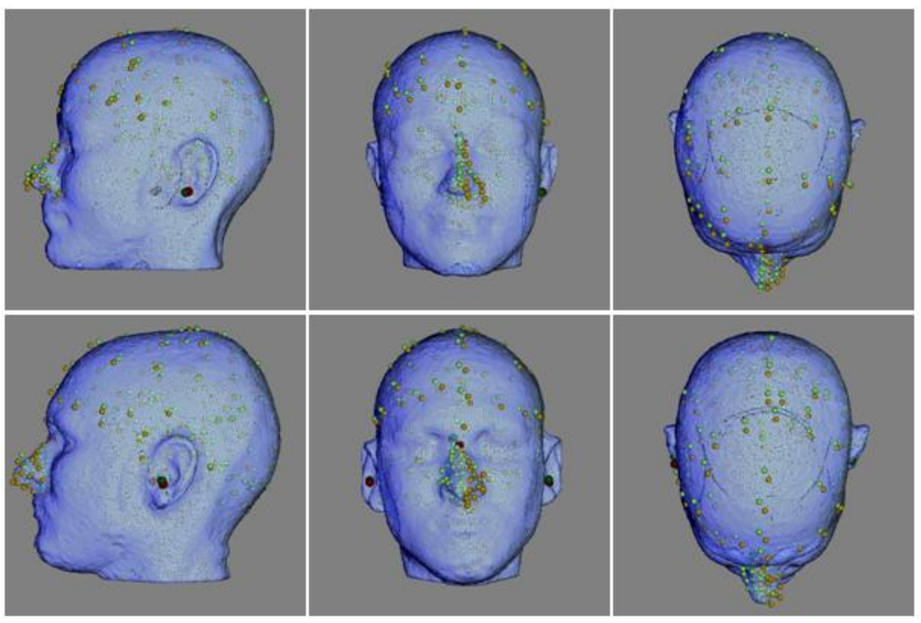

Figure 4: Registration of recorded surface points to a segmented MRI surface. Comparing a registration performed by the ICP algorithm with a registration performed by the fwICP algorithm.
Light/dark green: Registration with ICP algorithm. fiducials are shown in dark green, other points in light green.
Orange/red: Registration with fwICP algorithm. fiducials are shown in red, other points in orange.

Table 1: The used point clouds.

#	Subject Nr.	Number of points	Recorded surface areas
A	1	104	Parietal, frontal bone
B	1	83	Parietal, frontal bone
C	1	122	Parietal, frontal bone, nose
D	1	127	Parietal, frontal bone, nose
E	1	141	Parietal, frontal cheek-bone, nose
F	2	117	Parietal, frontal bone
G	2	147	Parietal, frontal bone, nose
H	2	128	Parietal, frontal, cheek-bone

Table 2: Resulting mean distances per point cloud.

#	Manual	ICP	fwICP
	Mean distance [mm]		
A	7.76	3.72	3.82
B	5.15	2.66	4.05
C	5.09	2.81	4.02
D	6.16	3.16	3.76
E	4.09	3.32	3.57
F	4.24	2.32	2.83
G	4.25	3.13	4.00
H	4.10	3.74	3.78

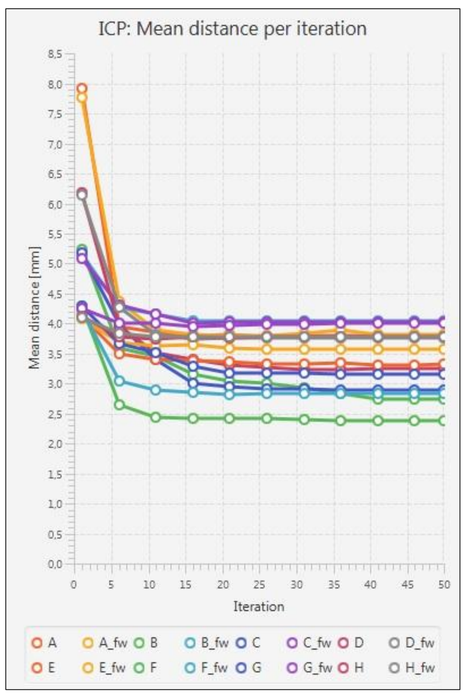

Figure 5: Graph showing the progression of mean distances per iterative step.
Start distance (0 iterations) is the manual alignment.

Conclusions

- Registration with ICP algorithm often achieves better results than manual registration.
- In some cases, using fwICP algorithm achieves best results regarding fiducial positioning.
- Deformation of the point cloud has negative influence on the registrations quality.
- Therefore, number of recorded points is less important than their location on the surface:
  - use face characteristics to improve registration (i.e. cheekbone, nasal bone)
  - avoid soft, deformable areas (i.e. nasal wings) as they lead to deformation
- Undeformed, naive point clouds including characteristic areas should achieve almost perfect registration to the segmented MRI surface.

Outlook

- Prevent deformation of point clouds during recording with Polhemus digitizer.
- Find the best point clouds for registration.
- Test reproducibility on other subjects.
- Use method for localizing cortical activity in MEG → Optimization?

References

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