Westfälische Wilhelms-Universität Münster

IBB Institute for Biomagnetism and Biosignalanalysis

Different approaches to the tDCS optimization problem

Homölle S. [1], Wagner S.[1], Burger M.[2], Wolters CH.[1]

[1] Institute for Biomagnetism and Biosignalanalysis, University of Münster, 48149 Münster, Germany
[2] Institute for Computational and Applied Mathematics, University of Münster, 48149 Münster, Germany

Introduction

In the past different approaches were used to optimize tDCS current density vector fields [1]. The main goal of optimization is to achieve reasonable focality, orientation and intensity of the current density for a presumed target location.

Methods

- The computation of the current density $J = \sigma\nabla\Phi$ is done via the Laplace Equation $\nabla\cdot\sigma\nabla\Phi=0$ with inhomogeneous Neumann boundary condition at the electrodes. [3,4]
- For optimization we apply weighted least square (LS), maximal intensity (max. Intensity), linear constrained minimum variance (LCMV) [1] and alternating direction method of multipliers (ADDM-L1R) [2] approaches. Due to patient safeness the total current applied is limited by 2mA
- For comparison we defined different targets regions (Figure 1 black cones), computed the optimized stimulation protocols (Figure 1 red and blue dots) and calculated the target intensity (Table 1 Column 3), the averaged current density in the non-target regions (Table 1 Column 4), the averaged current densities in the direction of the target vector (Table 1 Column 5), a ratio of averaged current density in the target region and averaged current density in the non-target regions (Table 1 Column 6), the EMD between desired field and obtained field and the percentage of current density that is oriented parallel to the target vector (Table 1 Column 8).
- In our optimization, we used a six compartment (skin, skull compacta, skull spongiosa, CSF, grey matter and white matter) geometry-adapted hexahedral finite element head model with white matter anisotropy and 74 point electrodes (10/10 EEG system locations) are positioned on fixed locations at the head surface.

Results and Discussion

With regard to target intensity the max. Intensity approach yields the highest values, while the other approaches lead to very similar averaged current densites in the target region. Orientation is best adapted by LCMV, however the other approaches show nearly identical parallellity with the target vector. In case of focality ADMM-L1R shows the best ratio of averaged current density in the target region and averaged current density in the non-target regions.

All in all there is a trade-off between intensity, focality and parallelity, therefore the approach that fits best clearly depends on the the target and the needs of the experiment.

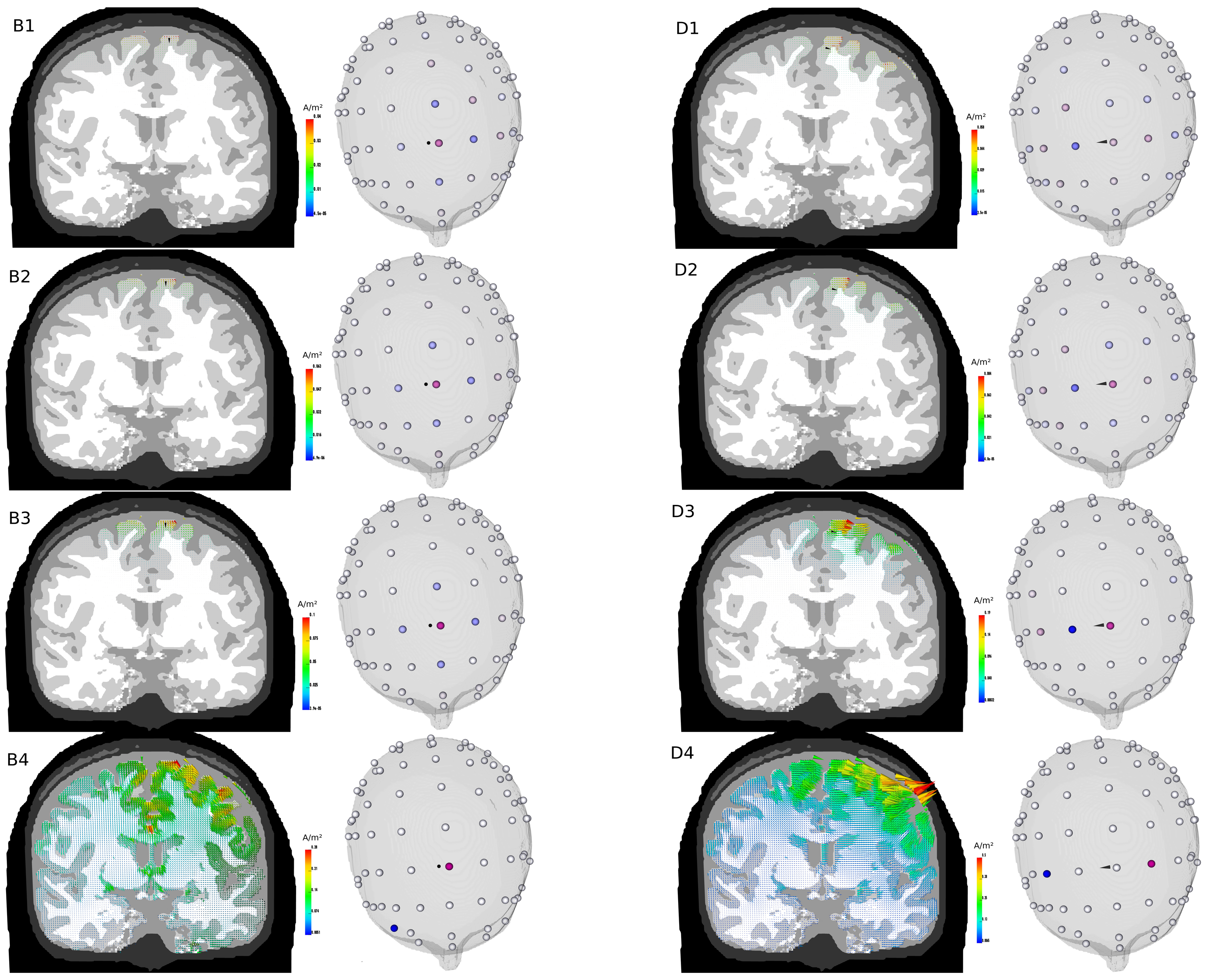

Figure 1.
Optimized current density for a radial target vector (B) and a tangential target vector (D). The optimization approaches are LCMV (1) ADMM-L1R (2) LS (3) max. Intensity (4).

Target	Method	$\frac{\int_{\Omega_t}\lvert BI_S\rvert\,dx}{\lvert\Omega_t\rvert}$ $[Am^{-2}]$	$\frac{\int_{\Omega\setminus\Omega_t}\lvert BI_S\rvert\,dx}{\lvert\Omega\setminus\Omega_t\rvert}$ $[Am^{-2}]$	$\frac{\int_{\Omega}\langle BI_S,e\rangle\,dx}{\lvert\Omega_t\rvert}$ $[Am^{-2}]$	FOC	EMD	PAR [%]
tangential	LS	0.09077	0.00527	0.08262	17.22	1647	91.02%
	LCMV	0.03196	0.00145	0.03079	22.04	1263	96.34%
	ADMM-L1R	0.03785	0.00151	0.03302	25.07	1096	87.24%
	max. Intensity	0.21188	0.04657	0.19783	4.55	7911	93.37%
radial	LS	0.07190	0.00154	0.06952	46.69	975	96.69%
	LCMV	0.03325	0.000695	0.03325	47.84	995	100%
	ADMM-L1R	0.04504	0.00071	0.04341	63.44	671	96.38%
	max. Intensity	0.19844	0.04890	0.18307	4.06	19729	92.25%
patch	LS	0.07329	0.00356	0.06667	20.59		90.97%
	LCMV	0.11490	0.00978	0.10708	11.75		93.19%
	ADMM-L1R	0.03700	0.00157	0.03330	23.57		90.00%
	max. Intensity	0.21195	0.04657	0.19883	4.55		93.80%
deep tangential	LS	0.08231	0.01973	0.08061	4.17	9144	97.93%
	LCMV	0.03180	0.00494	0.03162	6.44	4759	99.43%
	ADMM-L1R	0.01883	0.00249	0.01765	7.56	2153	96.29%
	max. Intensity	0.11700	0.05662	0.11476	2.07	21511	98.09%

Table 1.
Quantification of optimized current density. The averaged current density in the target area (third column), the averaged current density in non-target regions (fourth column), a ratio of averaged current density in the target region and averaged current density in the non-target regions (column sixth), the EMD between desired field and obtained field (column seventh) and the percentage of current density that is oriented parallel to the target vector (eighth column) is displayed for different target vectors (first column) and different optimization methods (second column).

References
[1] Dmochowski, J. P. et al. (2011), J Neural Eng 8.4:046011
[2] Boyd S et al. (2010), FTML 3.1:1-122
[3] Neuling T and Wagner S et al. (2012), Front. Psychiatry 3:83
[4] Wagner S et al. (2014), J Neural Eng 11.4:016002

Acknowledgement:
This research was supported by the priority program SPP1665 of the German Research Foundation, project WO1425/5-1

wissen.leben
WWU Münster

DFG