

Toward EEG-Based Brain State Recognition for Personalized Neuromodulation

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Outline

- Introduction
- Methods
- Results
- Conclusion

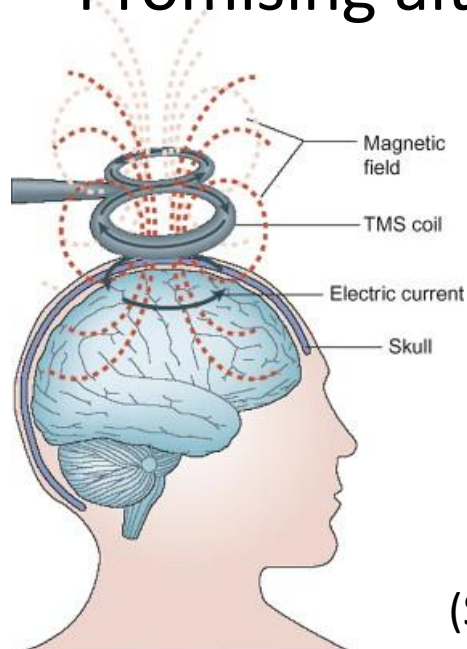
Introduction

Open-loop TMS

Brain-State-Dependent TMS

Open-loop TMS

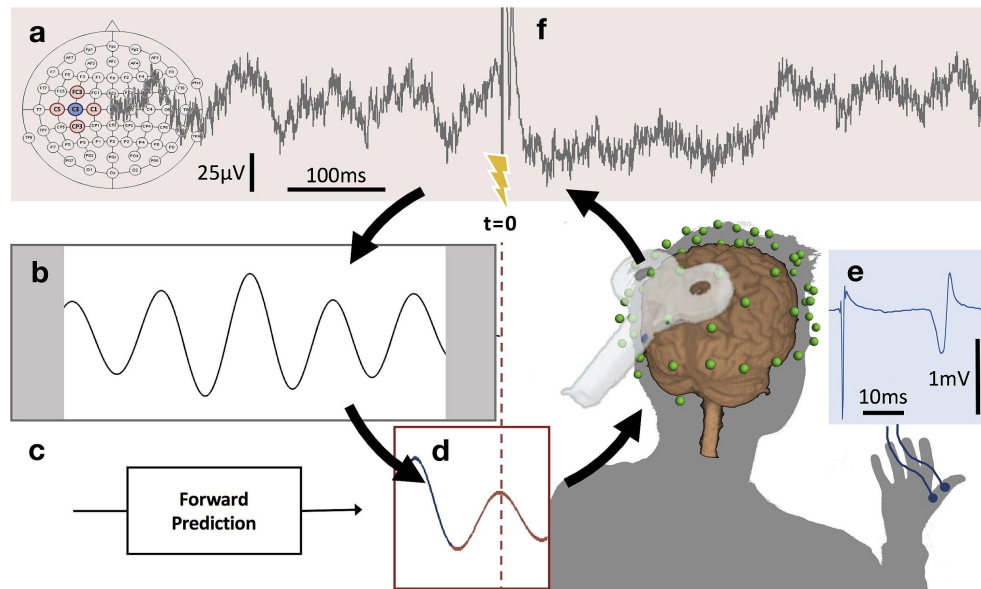
- rTMS therapy for TRD → low remission rate for conventional protocol (Fitzgerald, 2020)
- EEG oscillation may affect the TMS response (Schaworonkow, 2019)
- Promising alternative: Brain-state dependent TMS (Zrenner, 2018)



(Spronk, 2011)

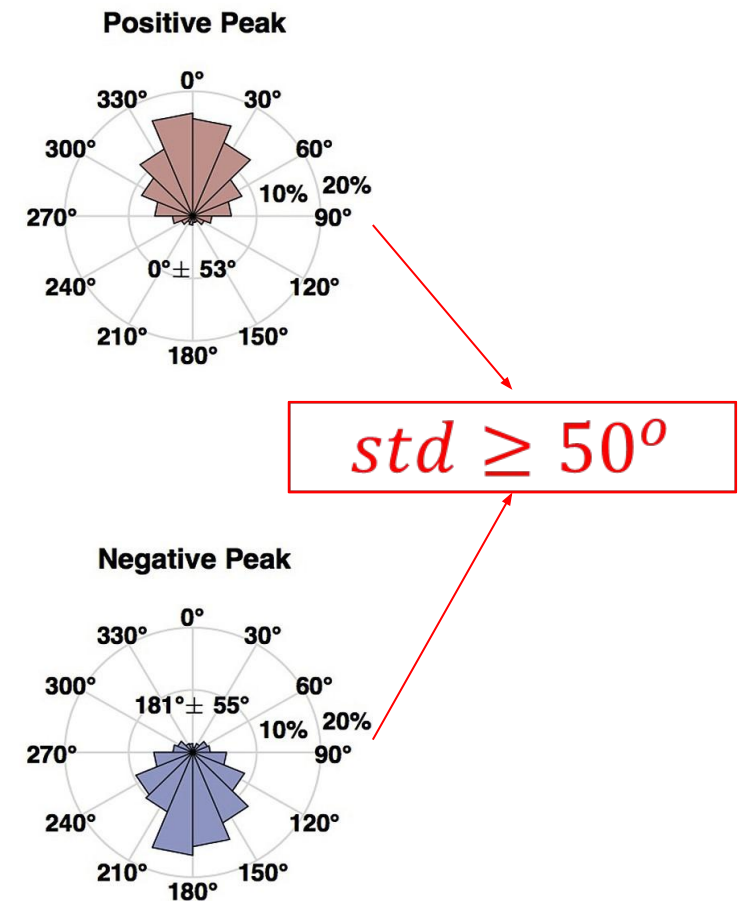
Brain-State-Dependent TMS

Brain-State-Dependent TMS



(Zrenner,2018)

Large standard deviation



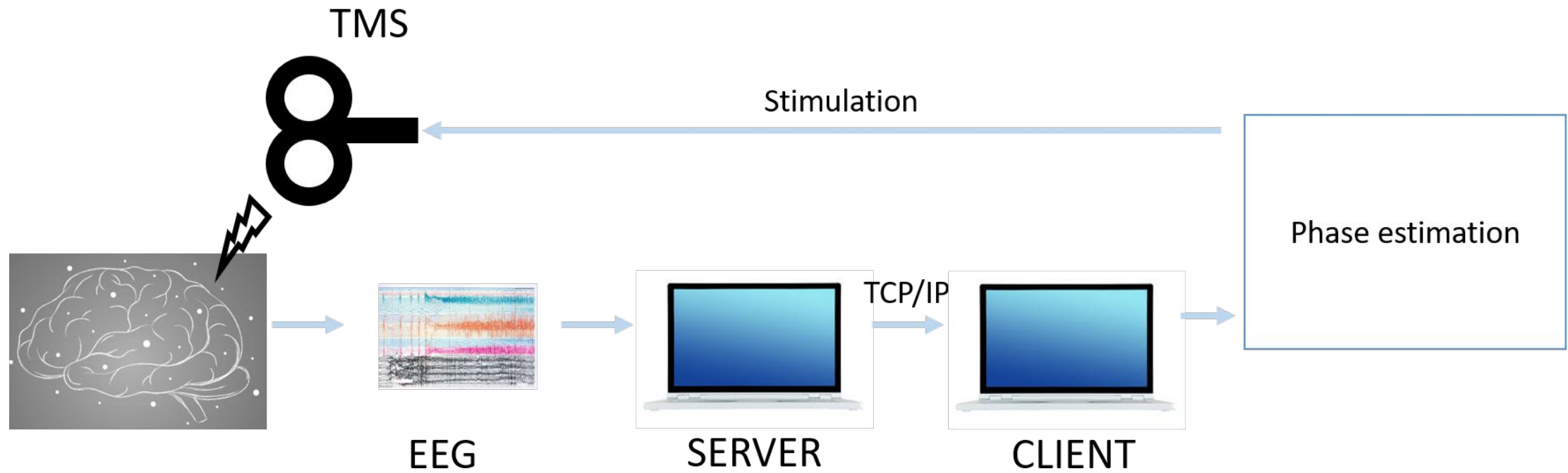
(Zrenner,2018)

Methods

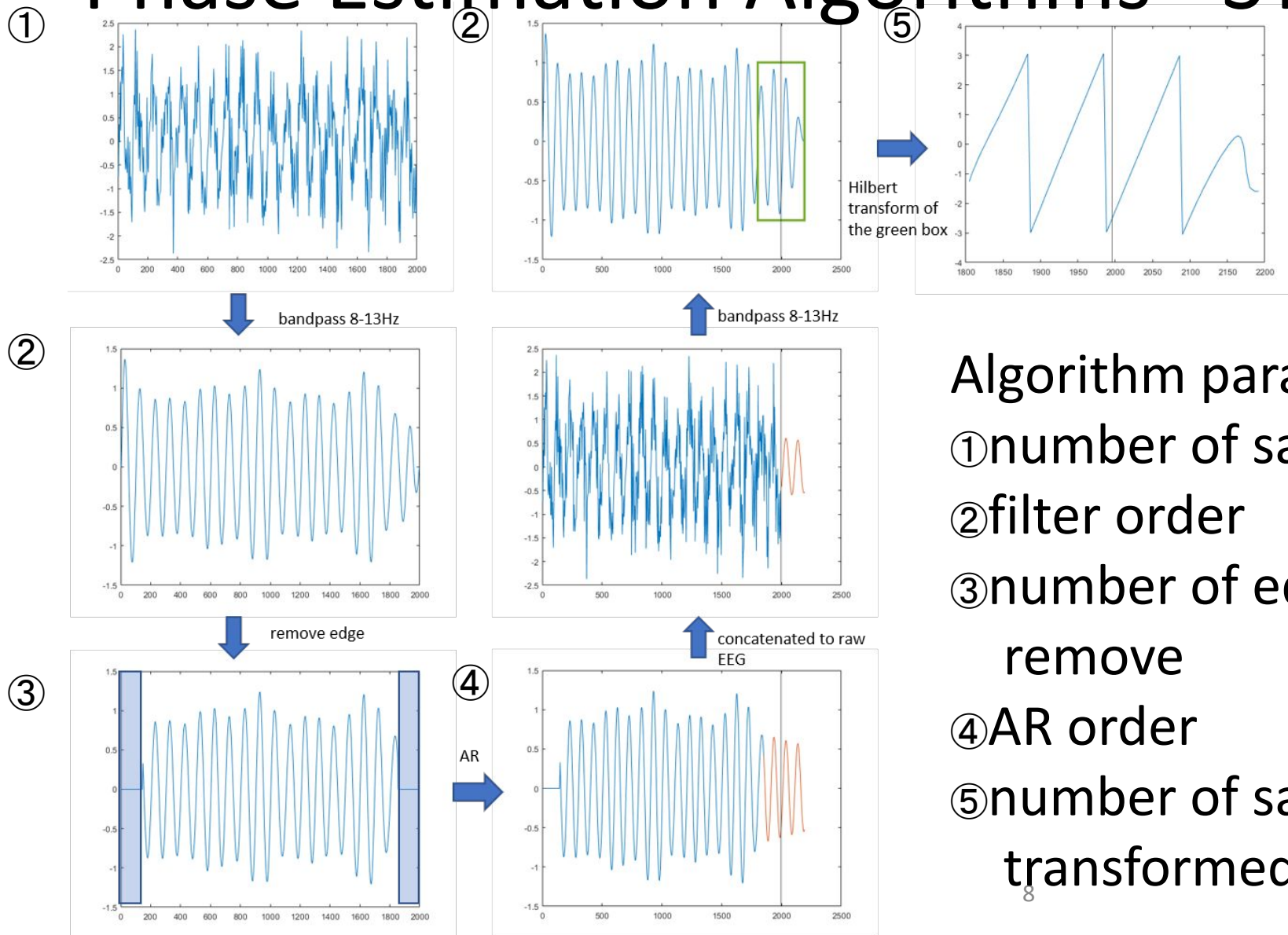
System Architecture

Phase Estimation Algorithm - STAR

System Architecture



Phase Estimation Algorithms - STAR



Algorithm parameters:

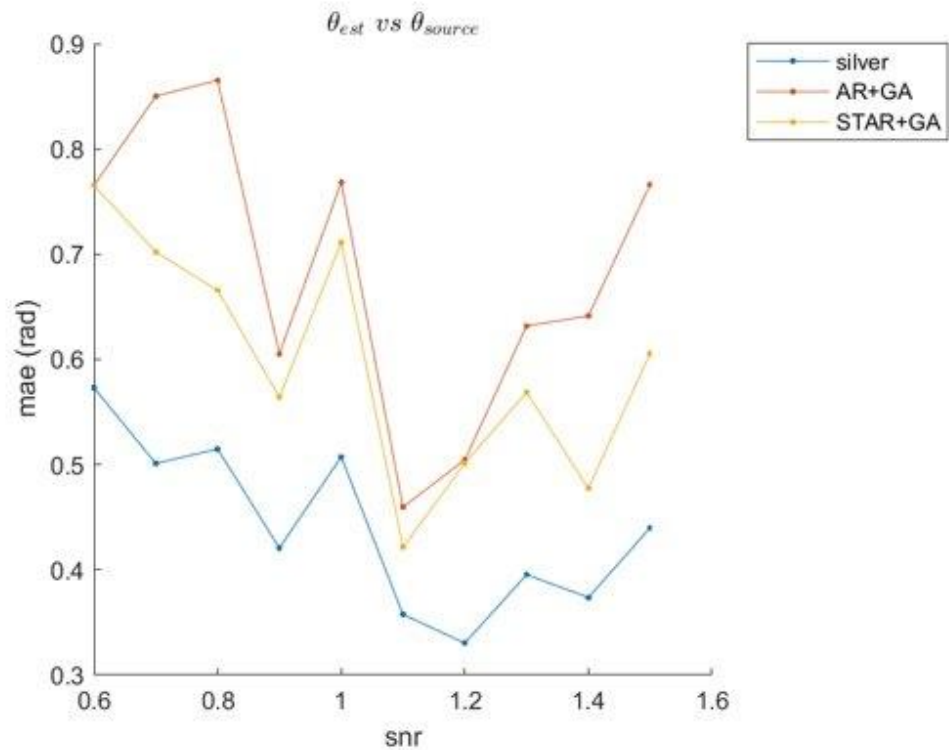
- ① number of samples to be filtered
- ② filter order
- ③ number of edge samples to remove
- ④ AR order
- ⑤ number of samples to be Hilbert transformed.

Results

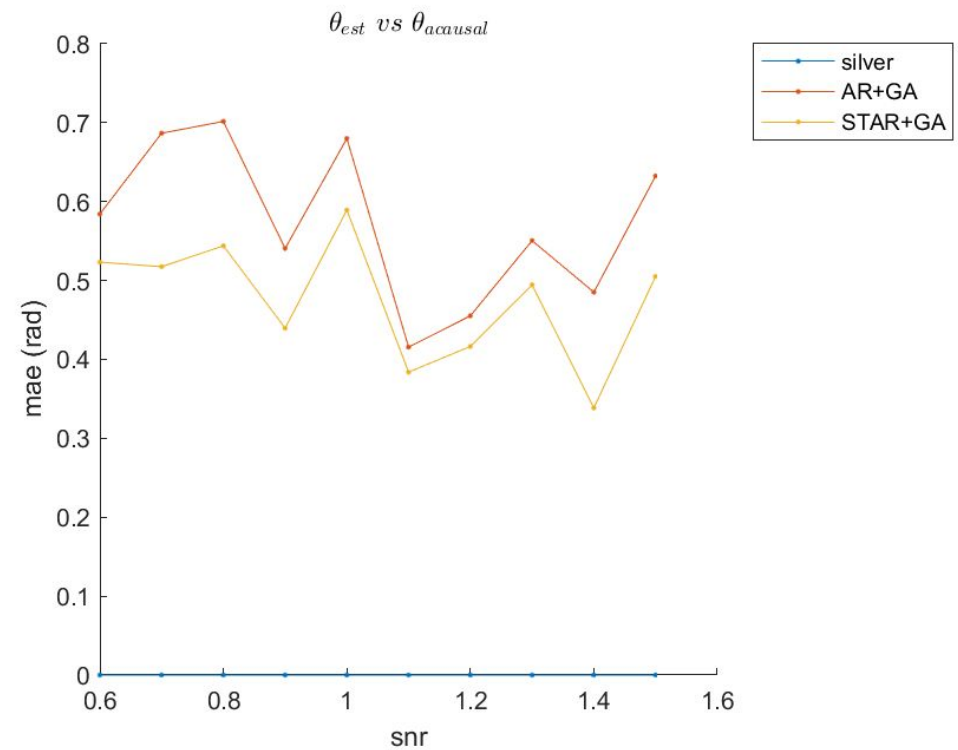
Accuracy of Phase Estimation

Accuracy of Phase Estimation

Ideal Ground truth: θ_{source}



Practical Ground truth: $\theta_{acausal}$



Conclusion

Conclusion

Conclusion

- We implemented a brain-state dependent TMS
- We proposed a causal phase estimation algorithm
 - Signal concatenation
 - Do not sacrifice the edge

Thank you

Questions or comments are welcome

References

- Fitzgerald, Paul B., et al. "A pragmatic randomized controlled trial exploring the relationship between pulse number and response to repetitive transcranial magnetic stimulation treatment in depression." *Brain stimulation* 13.1 (2020): 145-152.
- Schaworonkow, Natalie, et al. "EEG-triggered TMS reveals stronger brain state-dependent modulation of motor evoked potentials at weaker stimulation intensities." *Brain stimulation* 12.1 (2019): 110-118.

References

- Spronk, Desirée, Martijn Arns, and Paul B. Fitzgerald. "Repetitive transcranial magnetic stimulation in depression: protocols, mechanisms, and new developments." *Neurofeedback and neuromodulation techniques and applications*. Academic Press, 2011. 257-291.
- Zrenner, Christoph, et al. "Real-time EEG-defined excitability states determine efficacy of TMS-induced plasticity in human motor cortex." *Brain stimulation* 11.2 (2018): 374-389.
- Søren Dinesen Østergaard, *Depression: Response and Remission*, 2013

Simulated EEG

source

- $x(t) = a(t) \cos(\varphi + 2\pi ft) + n(t)$
- $a(t)$: *slow varying envelope*
- $n(t)$: *pink noise*
- f : *frequency of the underlying rhythm*