# A Comparative Evaluation of Electrical Field Visualization from EEG/tDCS

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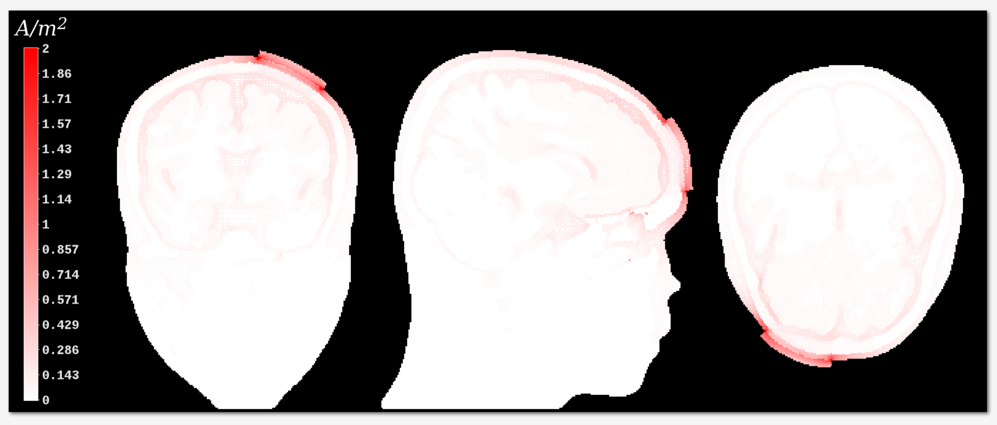
## 1 – Introduction

Electrical activity of neuronal populations is a crucial aspect of brain activity. This activity is not measured directly but recorded as electrical potential changes using head surface electrodes (electroencephalogram - EEG). Head surface electrodes can also be deployed to inject electrical currents in order to modulate brain activity (transcranial direct current stimulation, tDCS) for therapeutic purposes. For EEG and tDCS, electrical fields mediate between electrical signal sources and regions of interest. These fields can be very complicated in structure, and are influenced in a complex way by the conductivity profile of the human head. Visualization techniques play a central role to grasp the nature of those fields because such techniques allow for an effective conveyance of complex data and enable quick qualitative and quantitative assessments. Visualization can unveil structures and properties inside the data that statistical measures cannot. However, not every visualization technique is equally adequate for different analysis tasks and types of data. Additionally, the vast amount of available techniques makes it hard to decide for an optimal visualization approach.

We evaluate a number of widely used visualization techniques for their applicability in EEG and tDCS electrical field data. We show the advantages and disadvantages of each method with the help of the following figures.

**This poster summarizes:**
Eichelbaum S., Dannhauer M., Hlawitschka M., Brooks D., Knösche T., Scheuermann G.
**Visualizing Simulated Electrical Fields from Electroencephalography and Transcranial Electric Brain Stimulation: A Comparative Evaluation.** – NeuroImage, 2014, In Press.

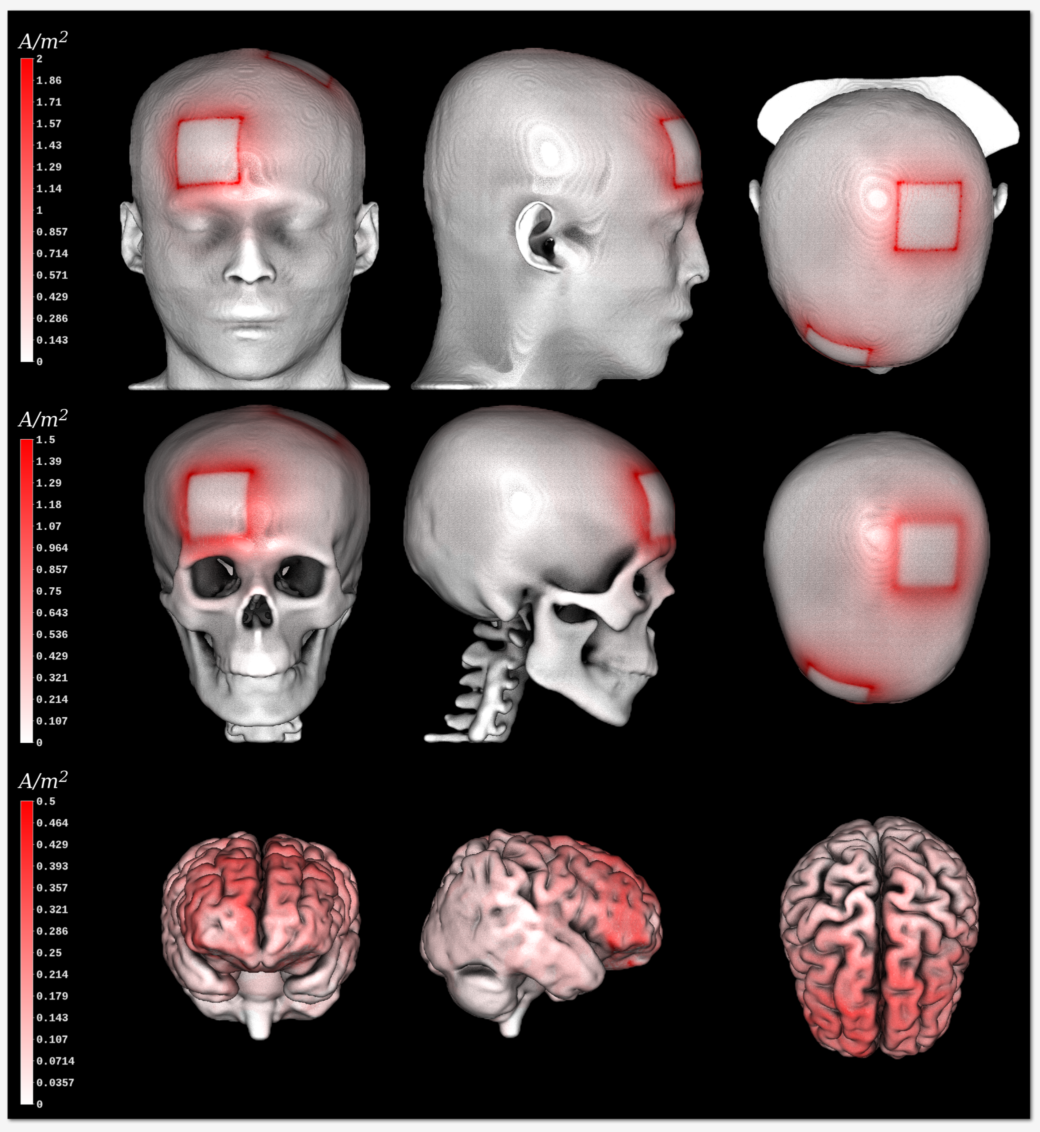
## 2 – The Problem



**Current density magnitude plot for tDCS example on cutting planes.** Although standard, slice-based visualizations suffer from missing spatial and directional information, which play an important role in electrical fields.

The following visualization methods can cope with the mentioned issues more or less well. Each one with its own advantages and disadvantages.

## 3a – Isosurfaces with Colormaps

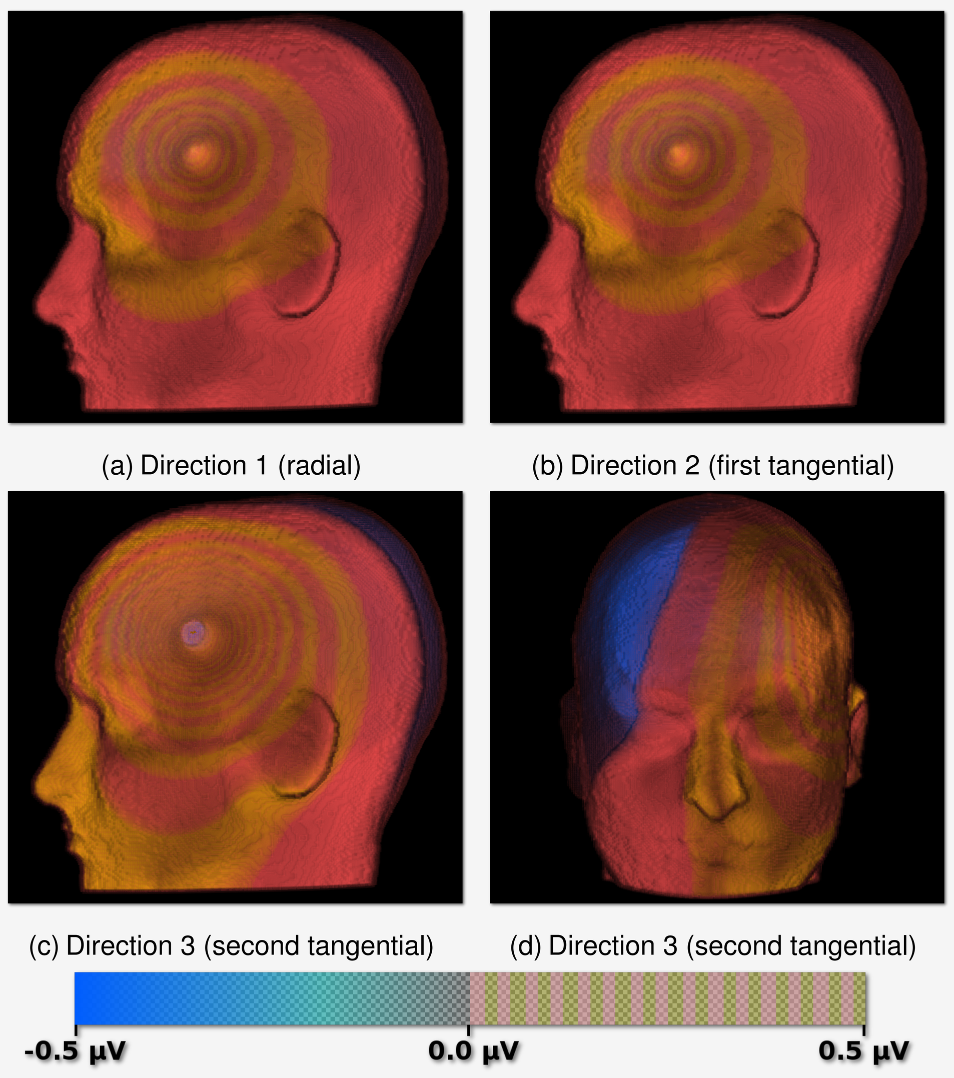


**Current density magnitude plot for tDCS example on material boundaries.**

+ Insights into spatial distribution of scalar fields.
+ Easy embedding of anatomical context.
– Only shows a part of volumetric structure.
– Prone to noise and sampling artifacts (surface creation).

*Most useful in the context of selectively showing global features and behavior.*

## 3b – Direct Volume Rendering (DVR)




(a) Direction 1 (radial) (b) Direction 2 (first tangential)

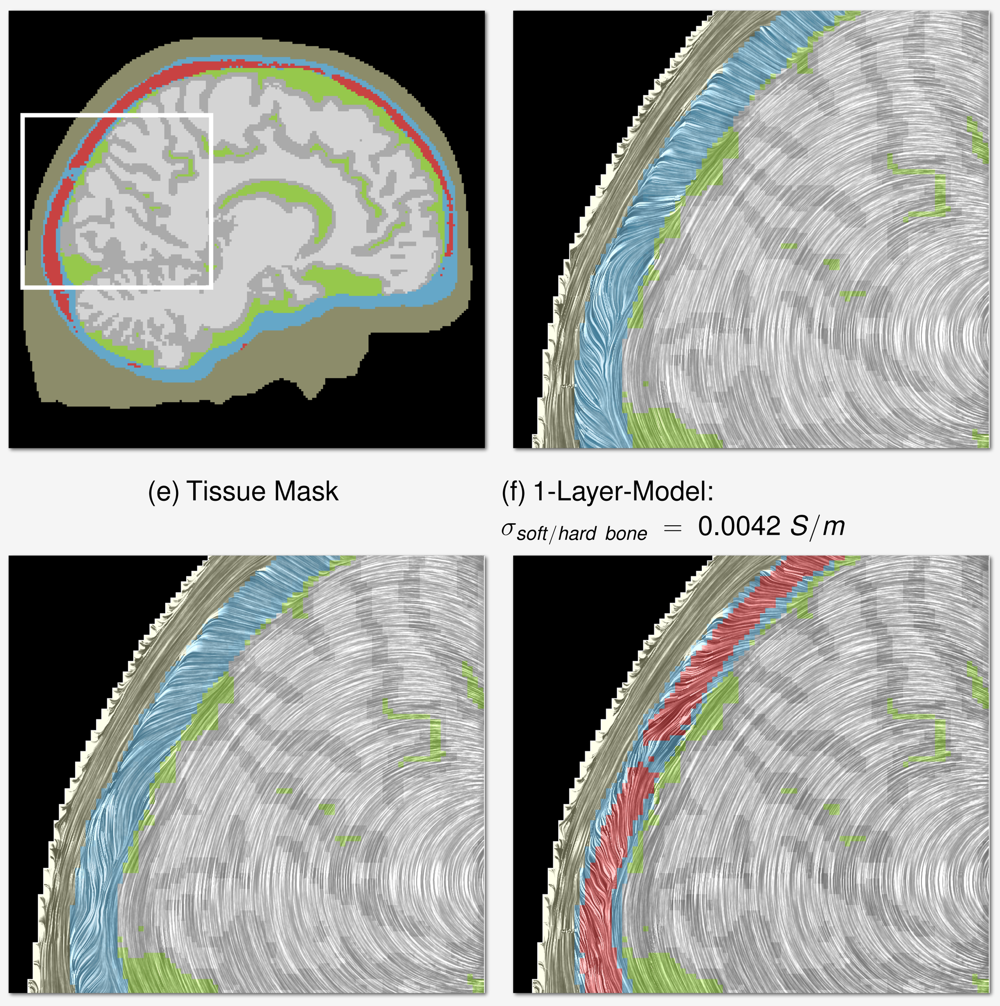
(c) Direction 3 (second tangential) (d) Direction 3 (second tangential)

**Direct Volume Rendering (DVR) for the potential difference fields for each source orientation in the Skull-Hole-Model.**

+ Insights into spatial structure and distribution of scalar fields in the entire volume.
+ Can avoid occlusion problems.
– Transfer function design is very domain- and case-specific.
– Anatomical context is hard to embed.

*Most useful in the context of catching multiple, global features in the entire volume.*

## 3c – Line Integral Convolution (LIC)



(e) Tissue Mask (f) 1-Layer-Model: $\sigma_{soft/hard\ bone} = 0.0042\ S/m$

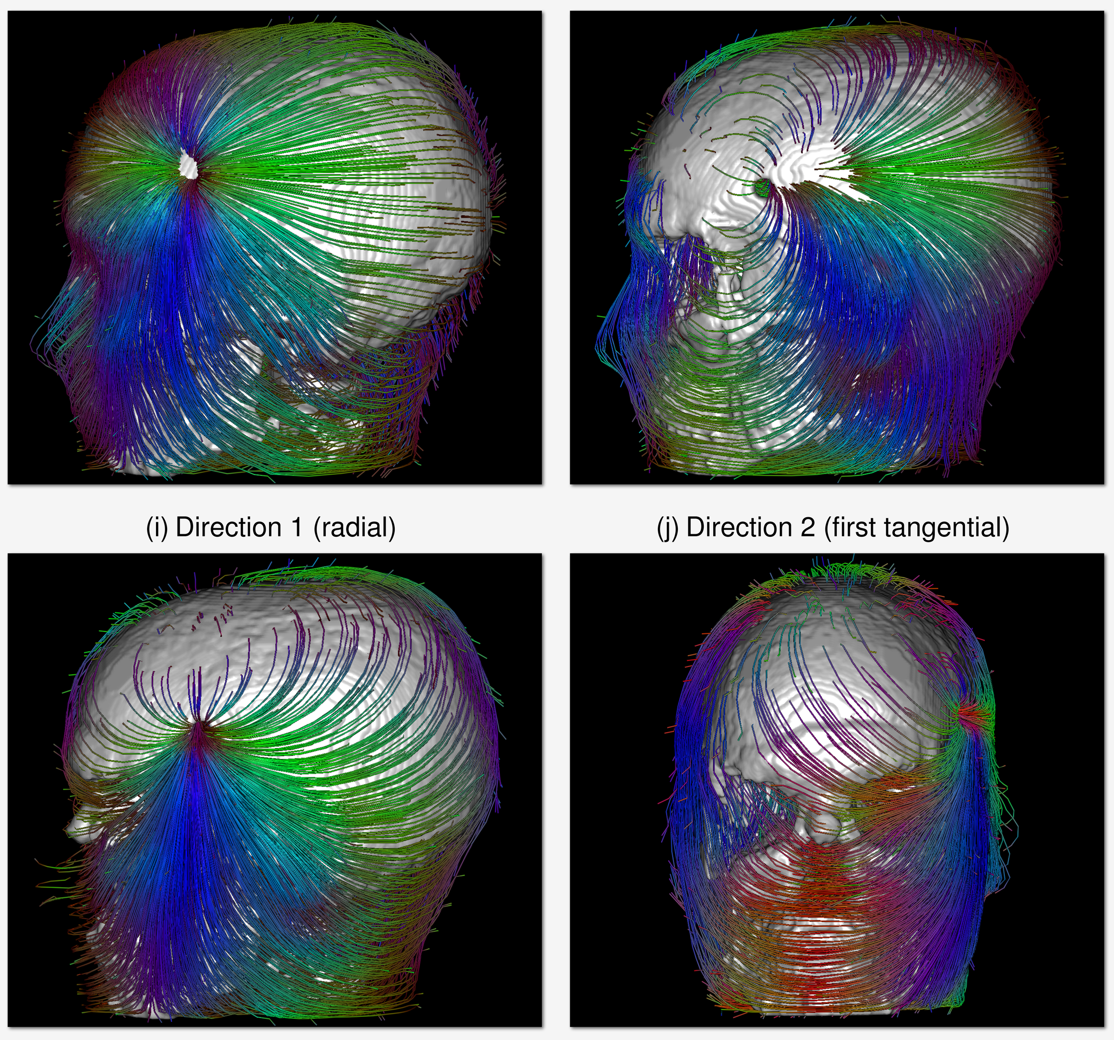
(g) 1-Layer-Model: $\sigma_{soft/hard\ bone} = 0.01245\ S/m$ (h) 3-Layer-Model: $\sigma_{soft\ bone} = 0.0287\ S/m$ and $\sigma_{hard\ bone} = 0.0064\ S/m$

**Line Integral Convolution (LIC) for different 1- and 3-Layer-Models.**

+ Insight into directional structures locally (focus on detail).
+ Good qualitative comparison among multiple images.
– Only depicts directional information; quantification difficult.
– Combination with colormaps can lead to misinterpretation.

*Most useful in the context of analyzing local and small-scale directional structures.*

## 3d – Streamlines



(i) Direction 1 (radial) (j) Direction 2 (first tangential)

(k) Direction 3 (second tangential) (l) Direction 3 (second tangential)

**Streamlines depict the electrical flow field in the Skull-Hole-Model.**

+ Insights into global, directional structures in 3D
– Occlusion problem (partially solvable by transfer functions and line filters).

*Most useful in the context of grasping major directional structures in 3D.*

## 4 – Results

We where able to identify the pros and cons of each method, and described the findings for each example with the different visualization methods.

During our evaluation, we found that we can divide the visualization techniques into two categories. 1) Visualization of local details (LIC). These methods usually profit from high grade of detail, but they suffer a missing spatial embedding. 2) Visualization of global structural information (Streamlines, volume and surface rendering). These methods provide insight into large scale field properties, including spatial correlations in the data, but tend to suffer from the visual occlusion problem and the difficult embedding into contextual data.

This means, there are visualization methods available for every kind of analysis and data, but they have to be chosen appropriately to really provide additional insight into the data.

## 5 – And even More

The previous figures gave an overview on what we have evaluated in the above mentioned paper. There, we introduce each visualization method and provide a detailed analysis of the visualized data. In this context, we compare each of the visualization methods for each one of the three example scenarios in detail.

The article can be downloaded at
`http://tinyurl.com/eichelbaum`
(this points to the URL
`http://www.sebastian-eichelbaum.de/publications_eichelbaum2014a`)

## 6 – Acknowledgements

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## 7 – Visualized With