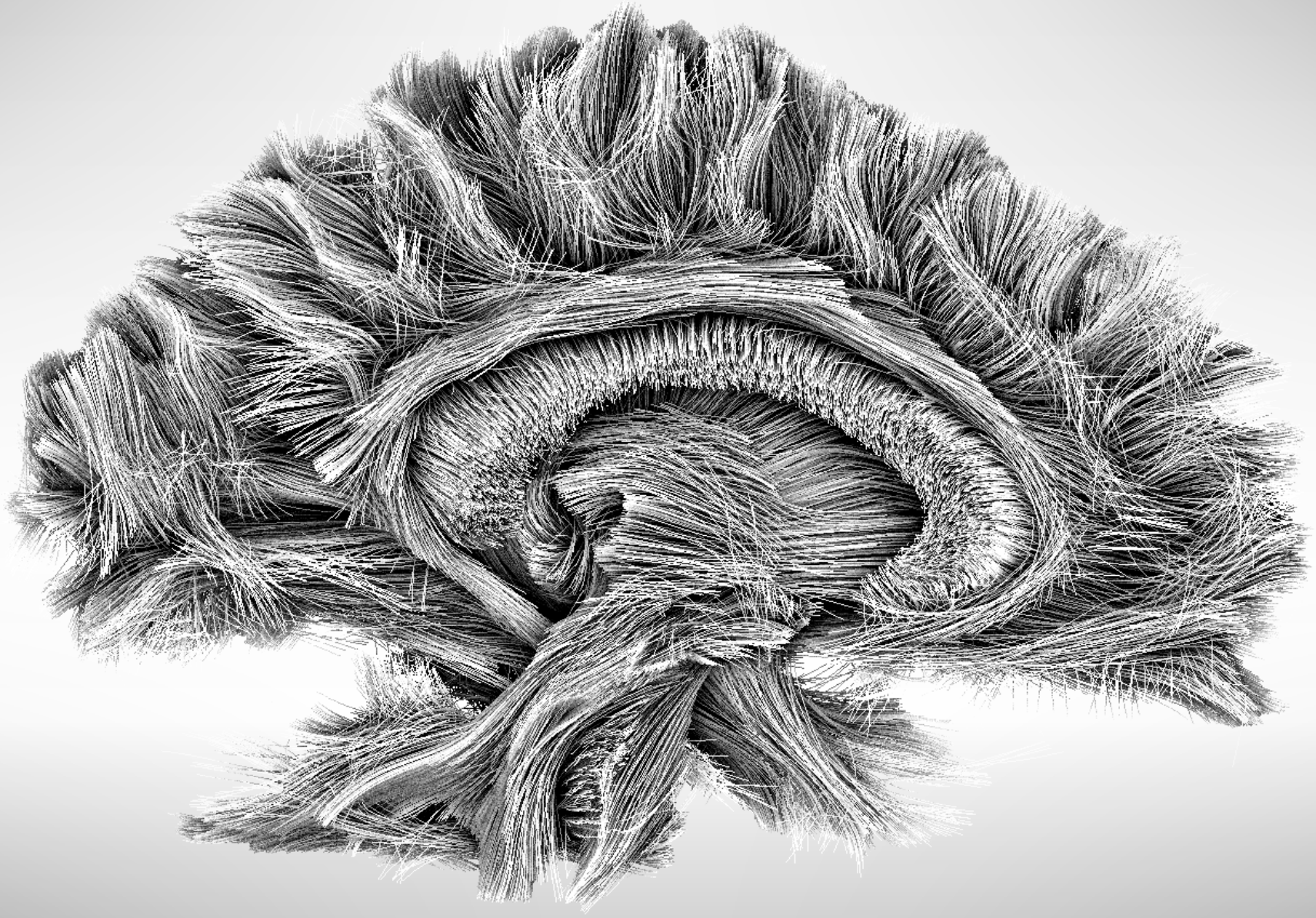
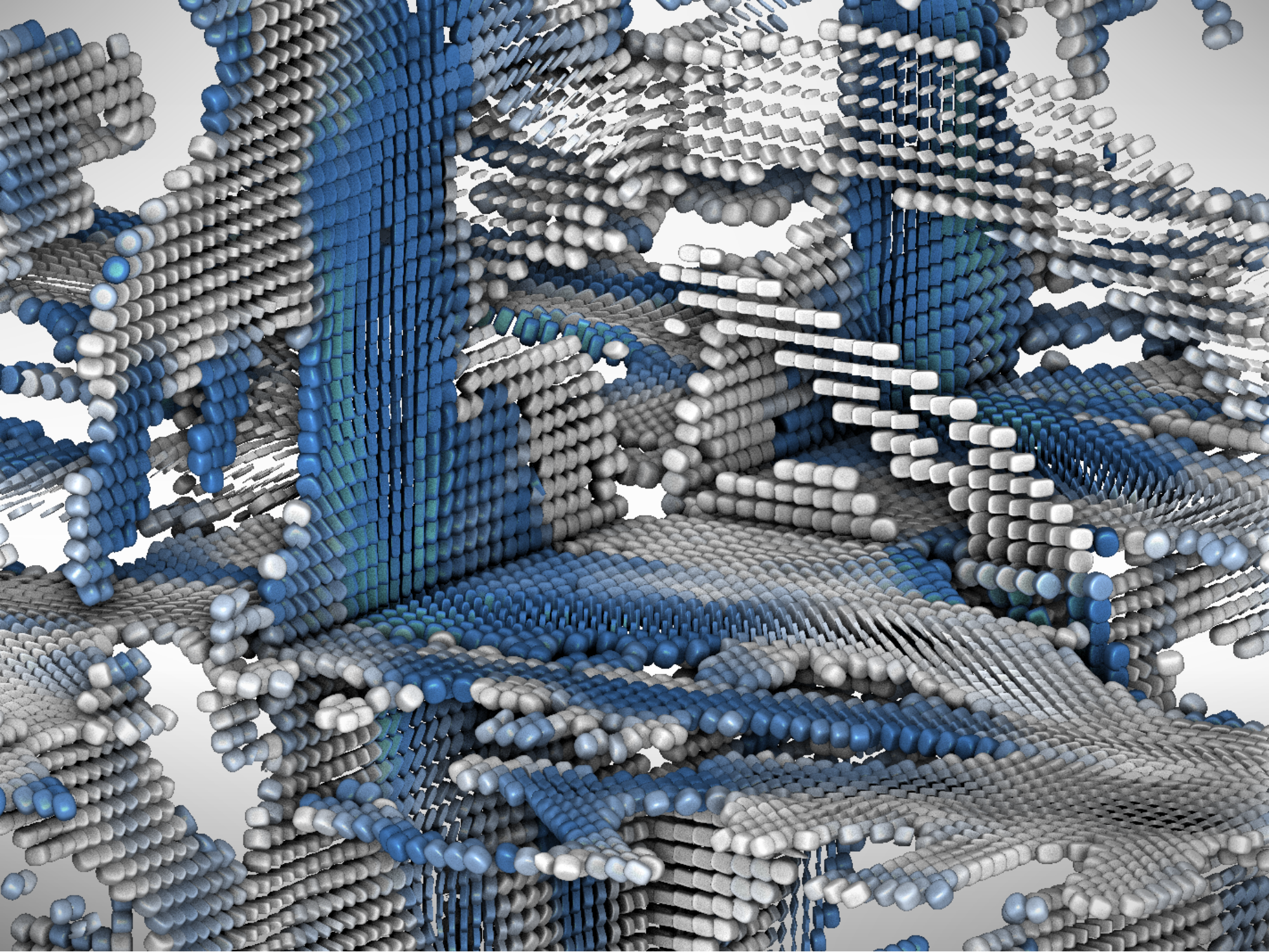
Applied Visualization in the Neurosciences and the Enhancement of Visualization through Computer Graphics

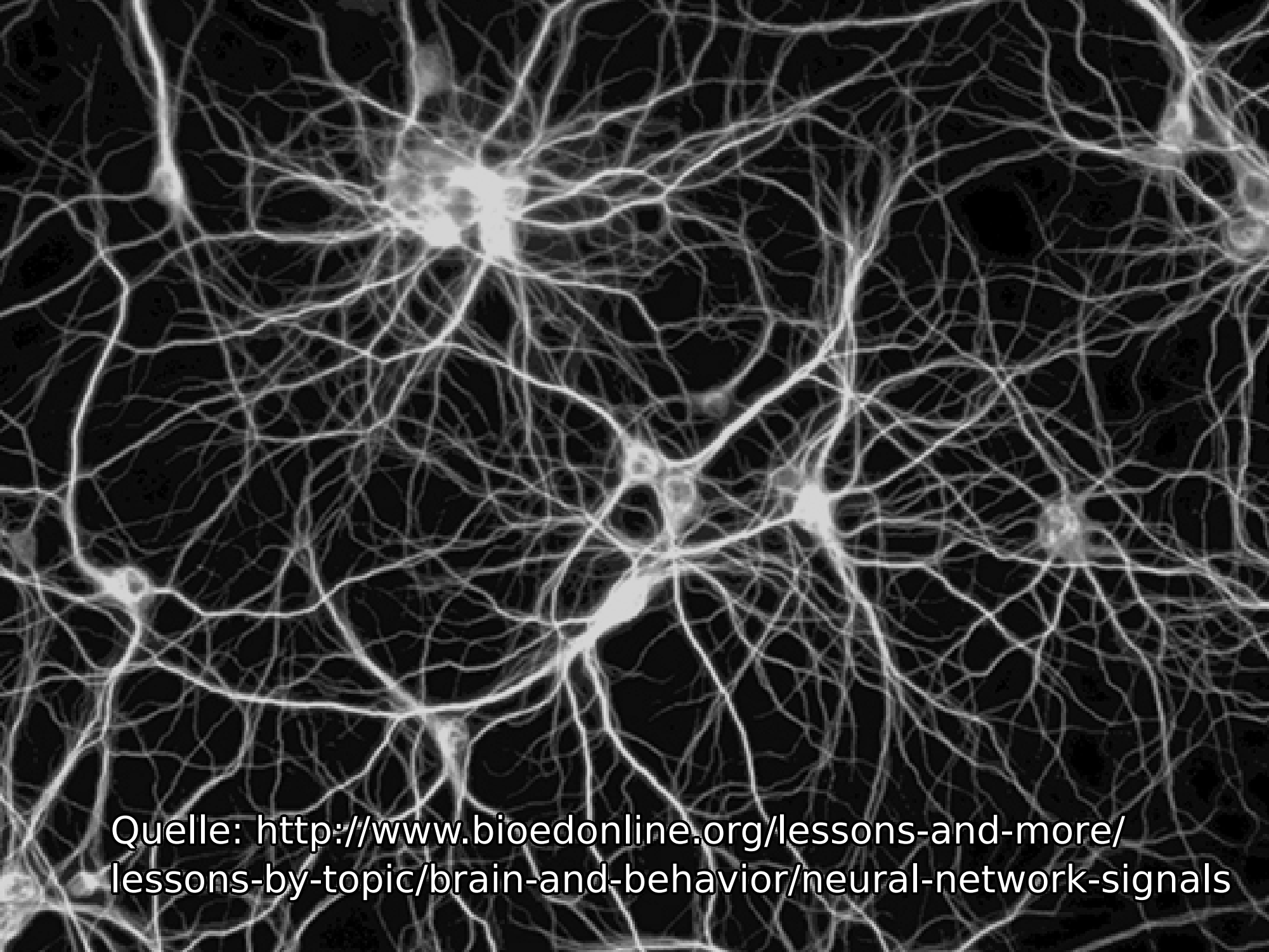
Verteidigung der Dissertation

27. November 2014

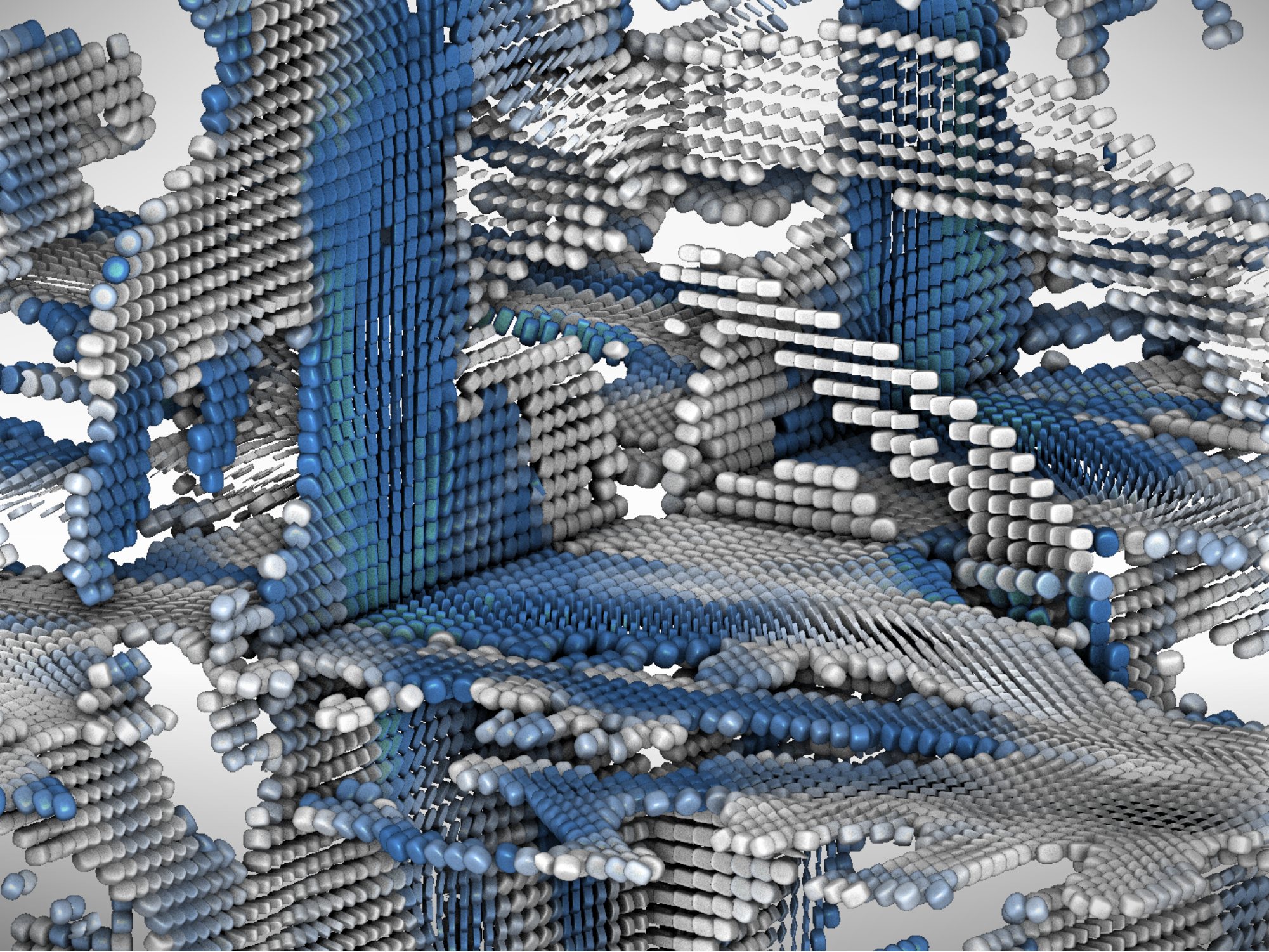
Sebastian Eichelbaum kontakt@sebastian-eichelbaum.de www.sebastian-eichelbaum.de

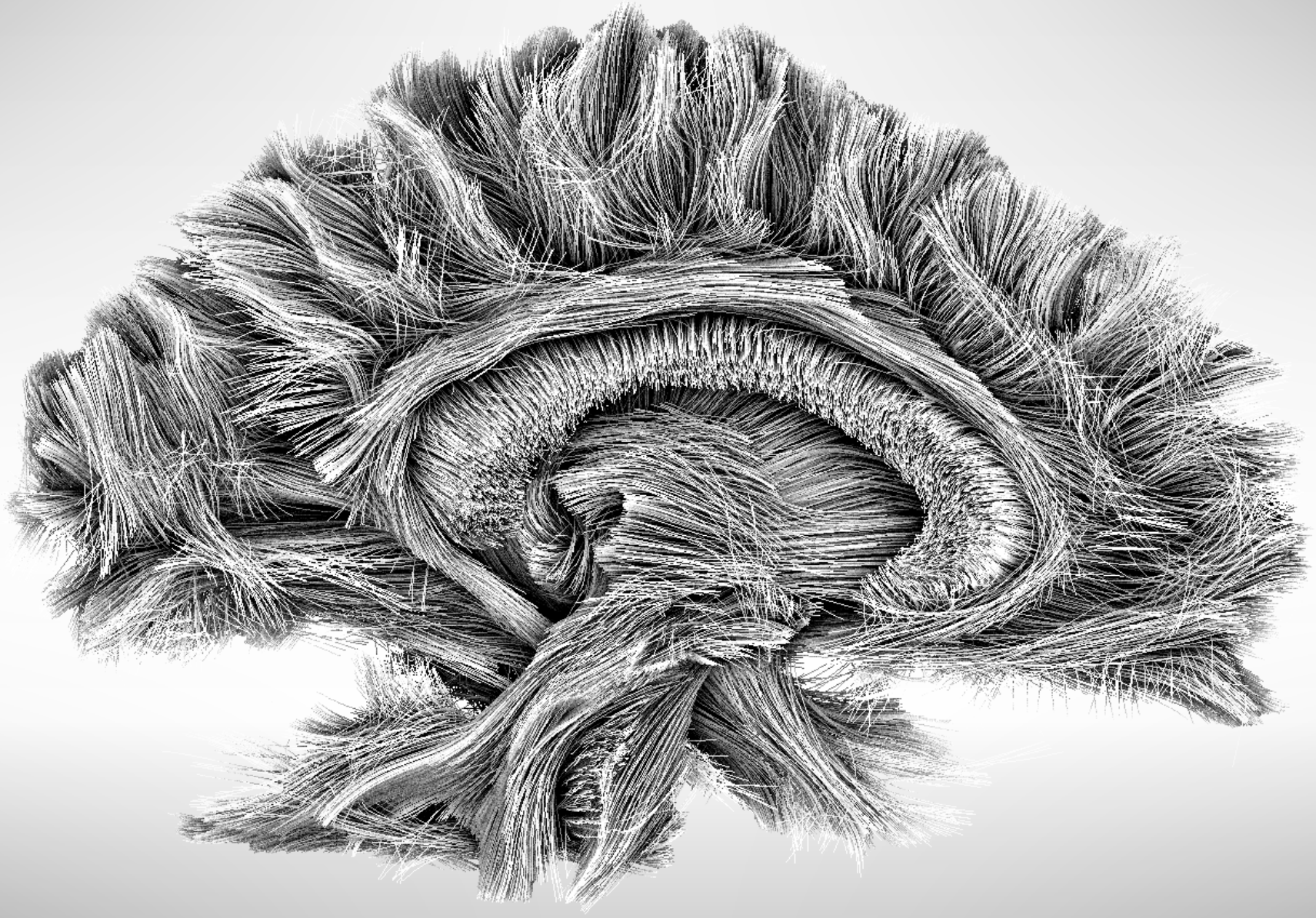






Quelle: http://www.bioedonline.org/lessons-and-more/lessons-by-topic/brain-and-behavior/neural-network-signals





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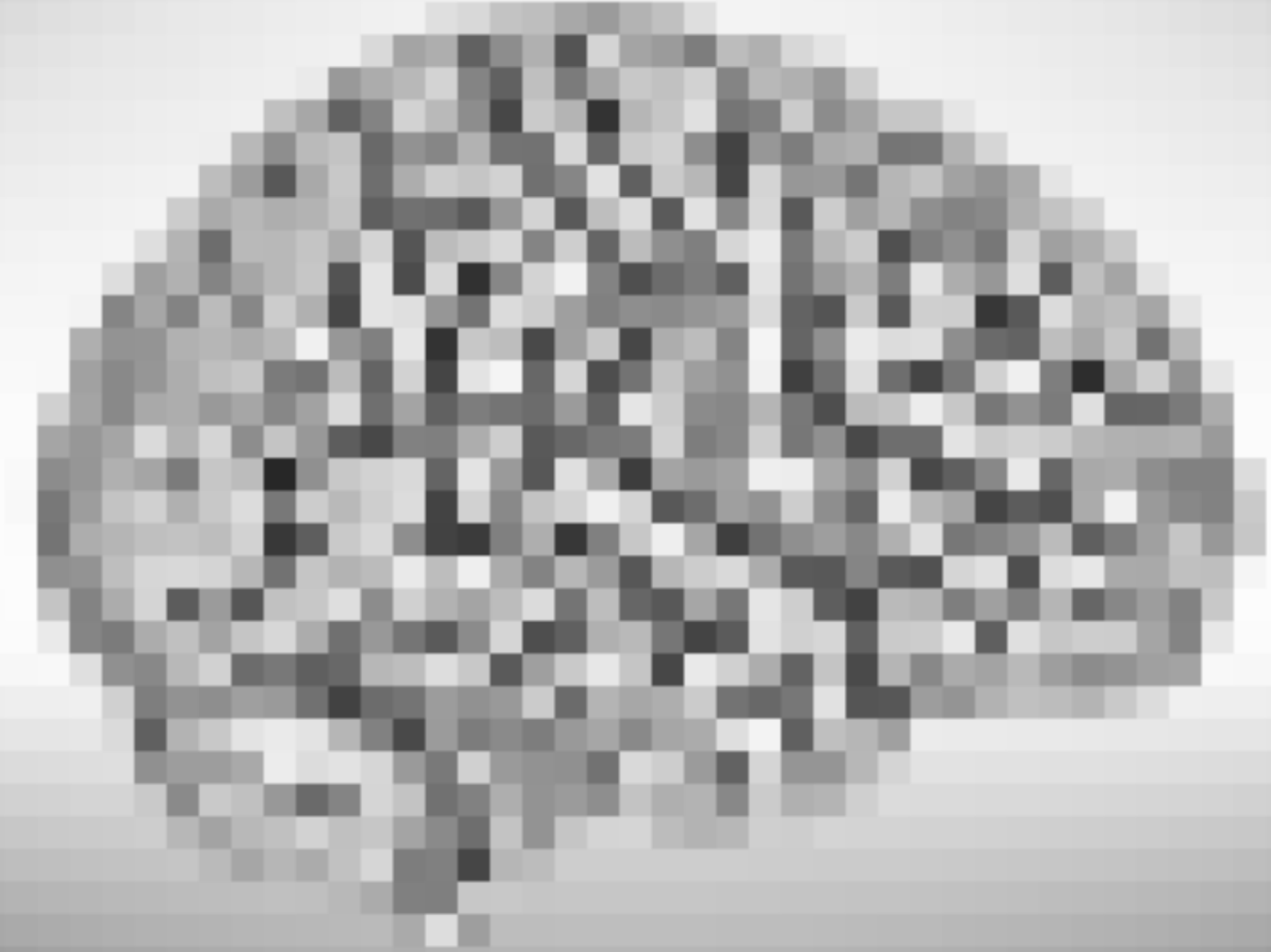
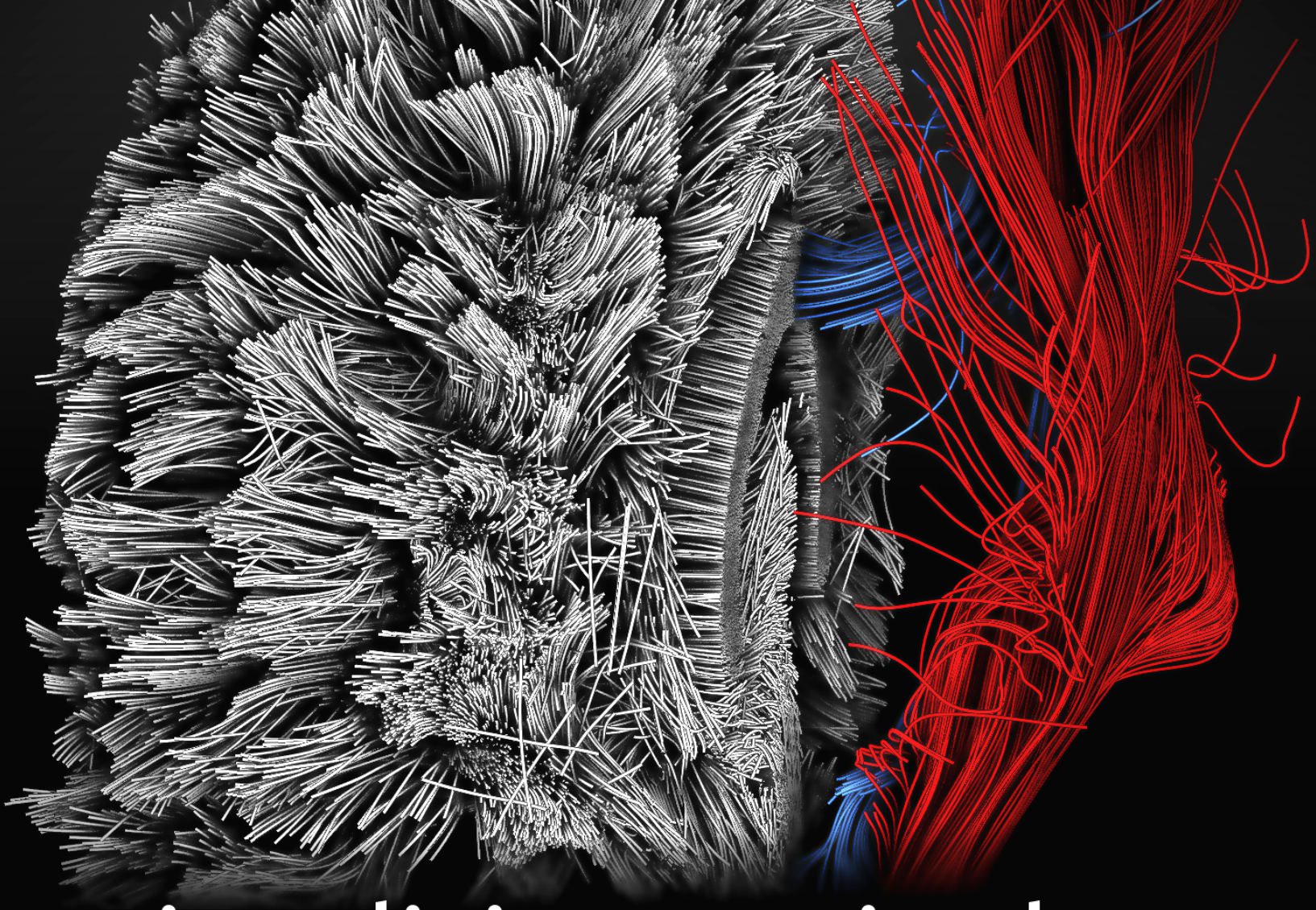


Inhalt

sebastian-eichebaum.de/pub14d

1 Visualisierung in den Neurowissenschaften
- Problemstellung
- Elektrische Felder im Gehirn
- Fazit

2 Computergrafik in der Visualisierung
- Problemstellung
- LineAO und PointAO
- Ergebnisse & Anwendung



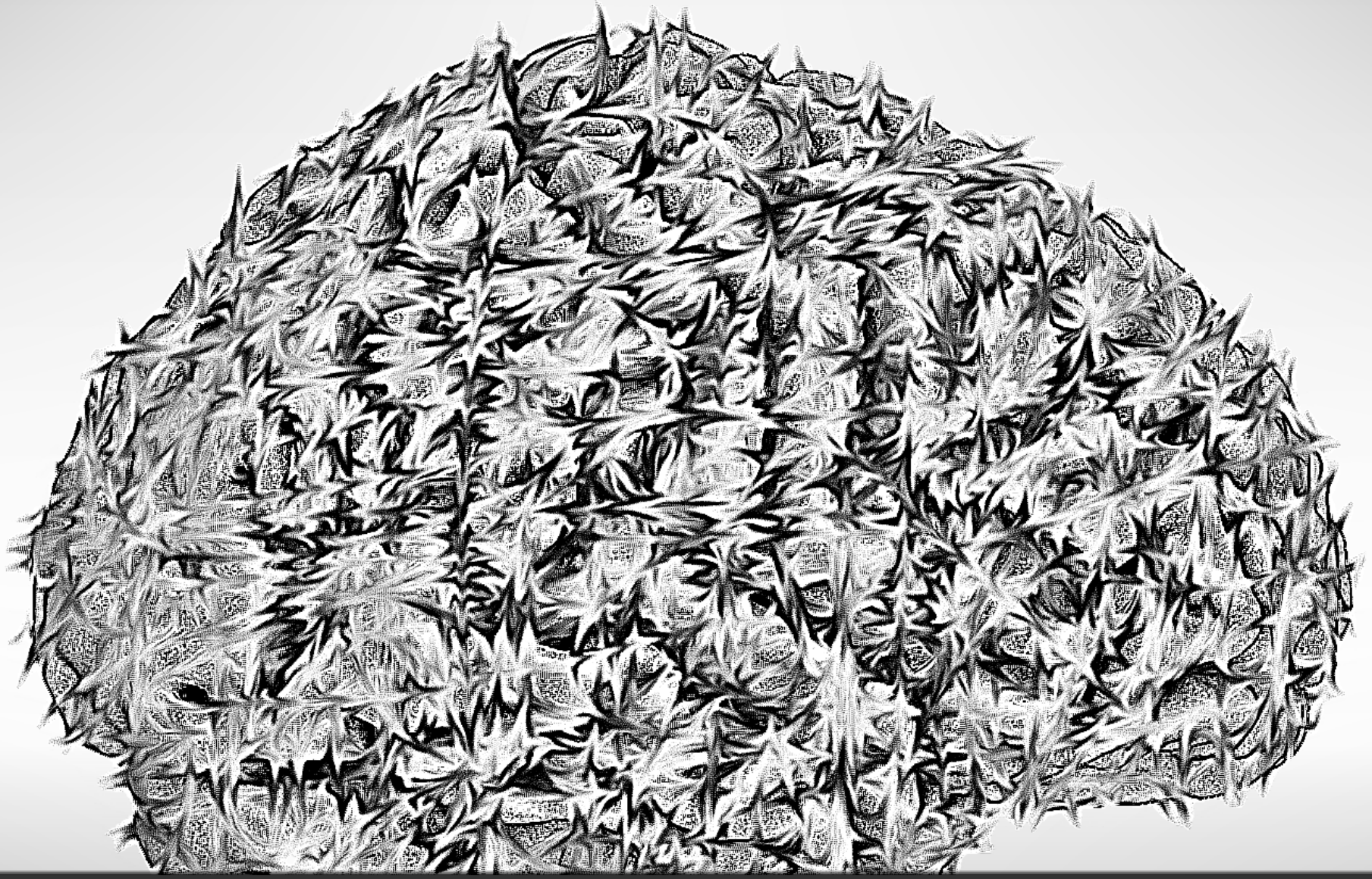
Teil 1

Visualisierung in den Neurowissenschaften

www.openwalnut.org

OpenWalnut: Open-Source Visualization Framework

- S. EICHELBAUM, M. GOLDAU, S. PHILIPS, A. REICHENBACH, R. SCHURADE, and A. WIEBEL. OpenWalnut: A New Tool for Multi-modal Visualization of the Human Brain. EG VCBM 2010 Posters. 2010
- S. EICHELBAUM, M. HLAWITSCHKA, A. WIEBEL, and G. SCHEUERMANN. OpenWalnut - An Open-Source Visualization System. Proceedings of the 6th High-End Visualization Workshop. 2010, 67–78
- S. EICHELBAUM, M. HLAWITSCHKA, and G. SCHEUERMANN. OpenWalnut: An Open-Source Tool for Visualization of Medical and Bio-Signal Data. Biomedical Engineering / Biomedizinische Technik. 2013



Zweckmäßigkeit: viel machbar ... aber nicht alles ist nützlich

Darstellung eines elektrischen Felds auf der Gehirnoberfläche
durch gezieltes verschmieren des Bildes entlang der Stromlinien.

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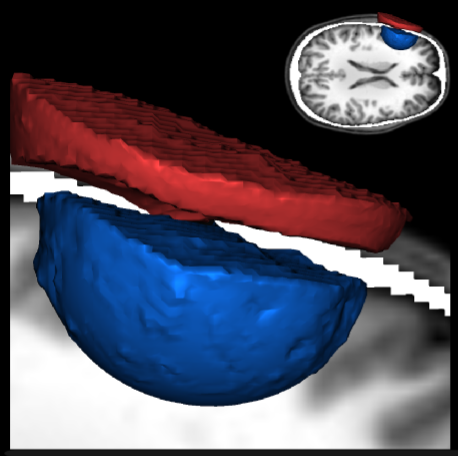
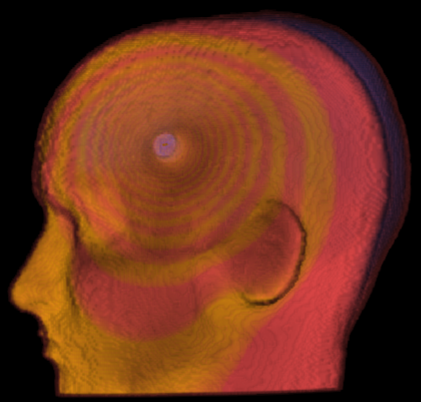
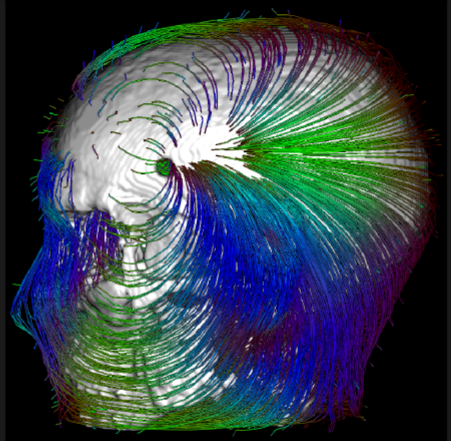
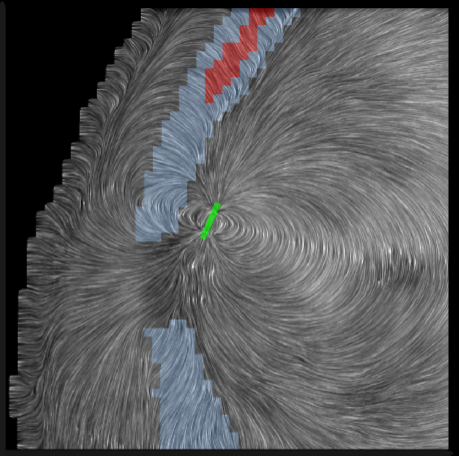
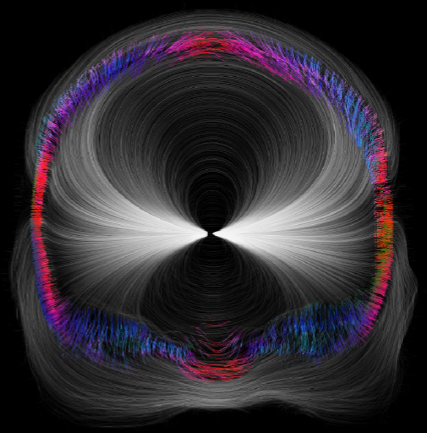
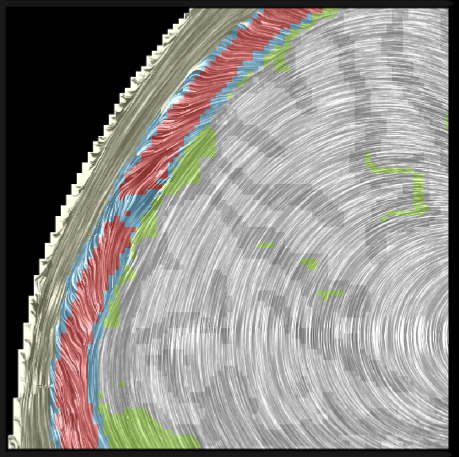
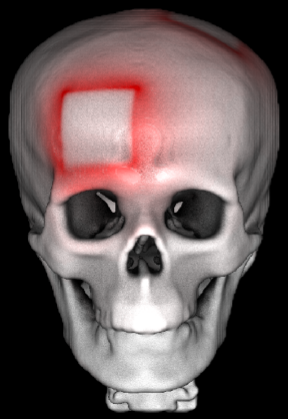
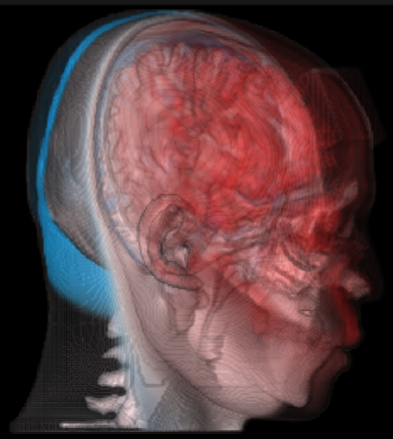
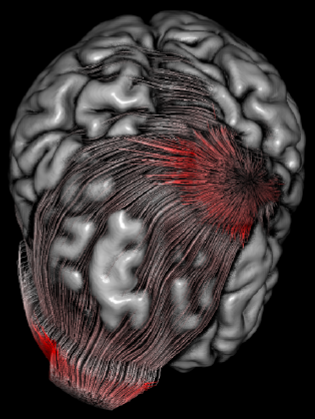
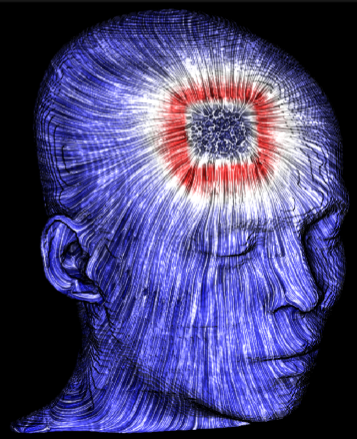
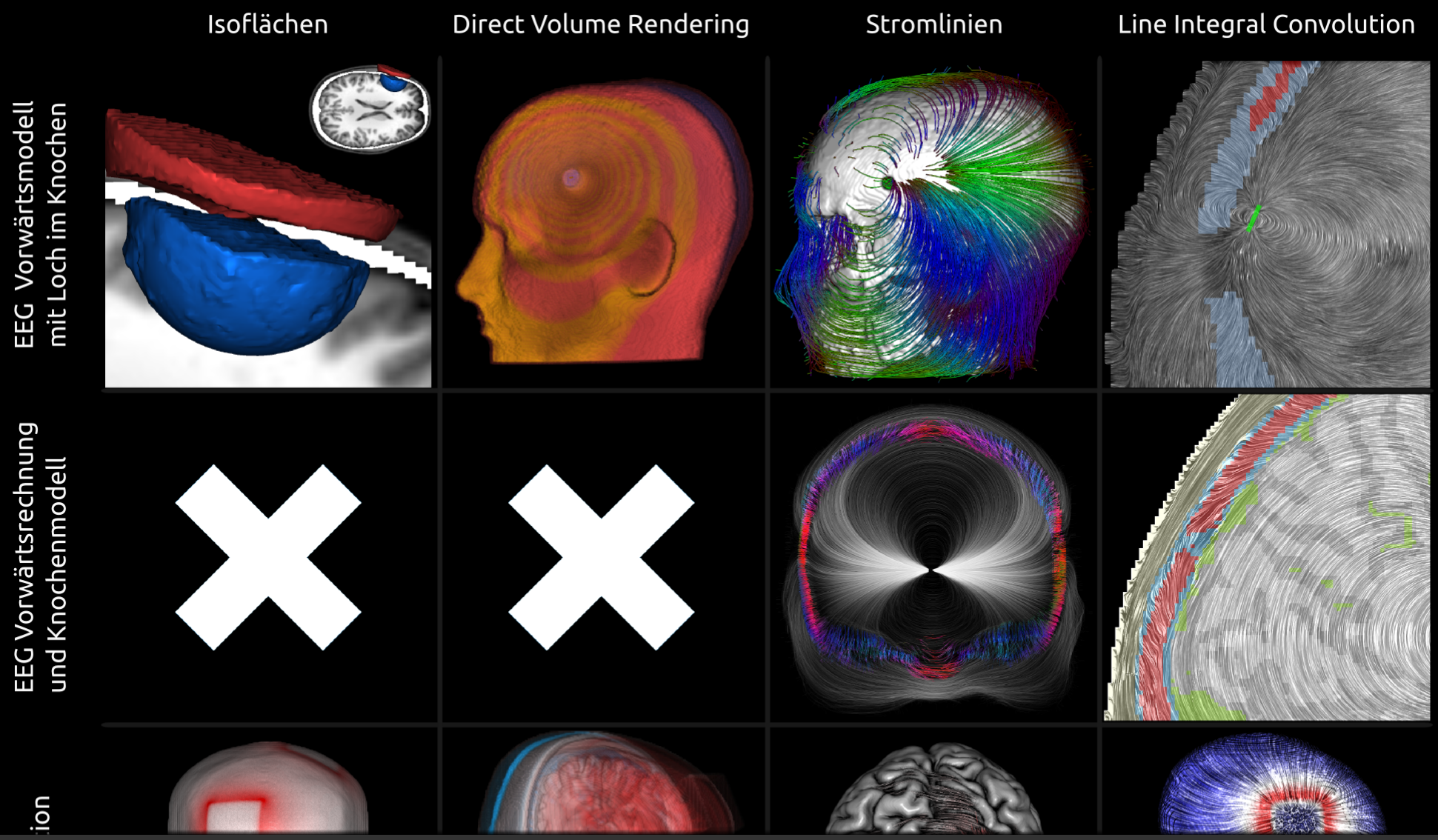
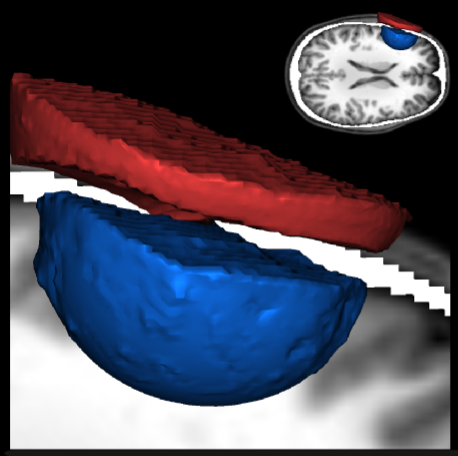
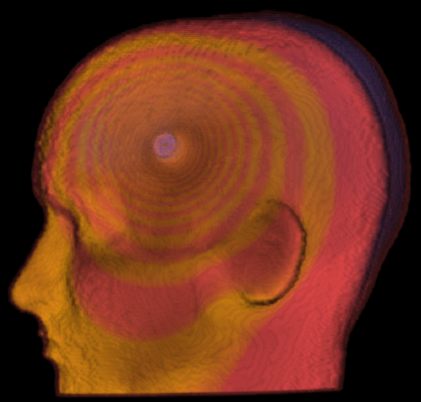
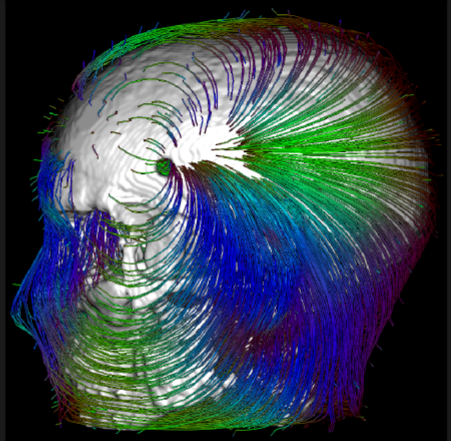
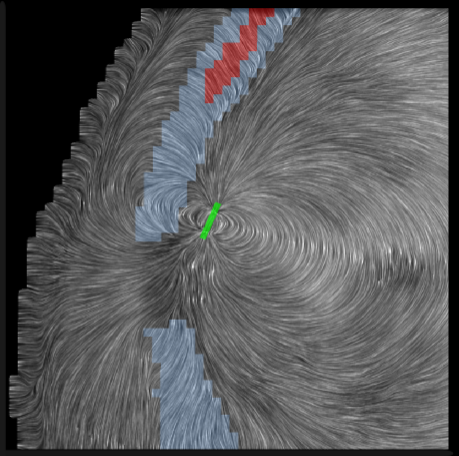
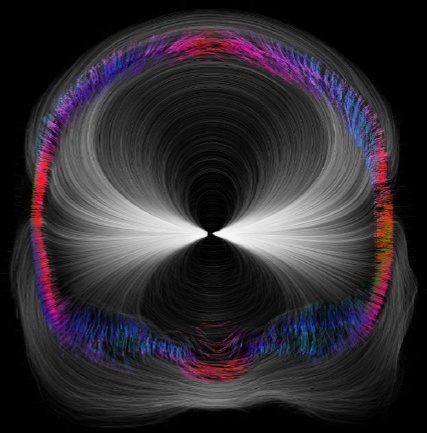
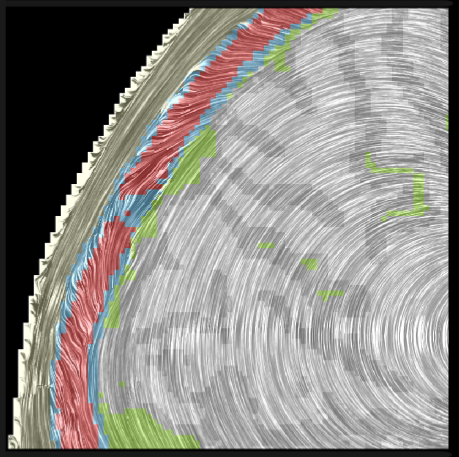
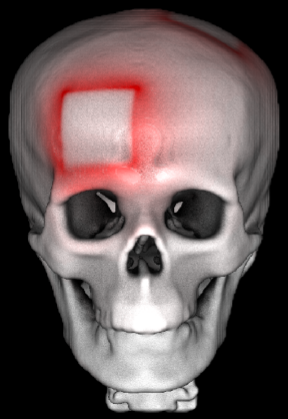
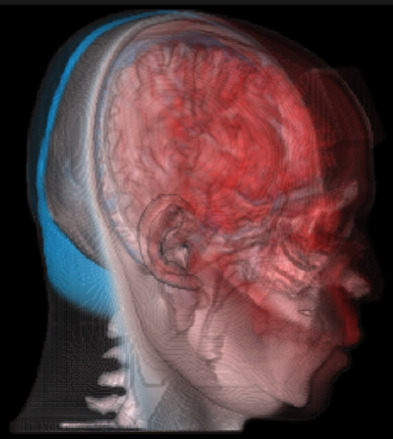
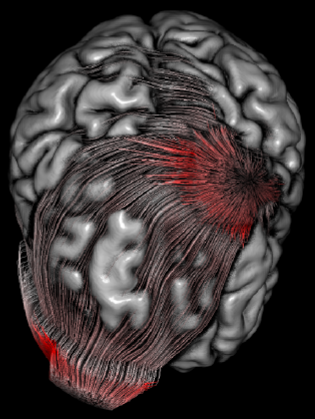
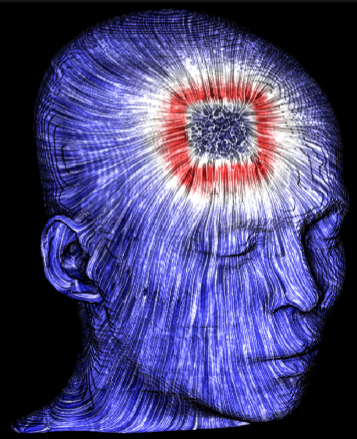
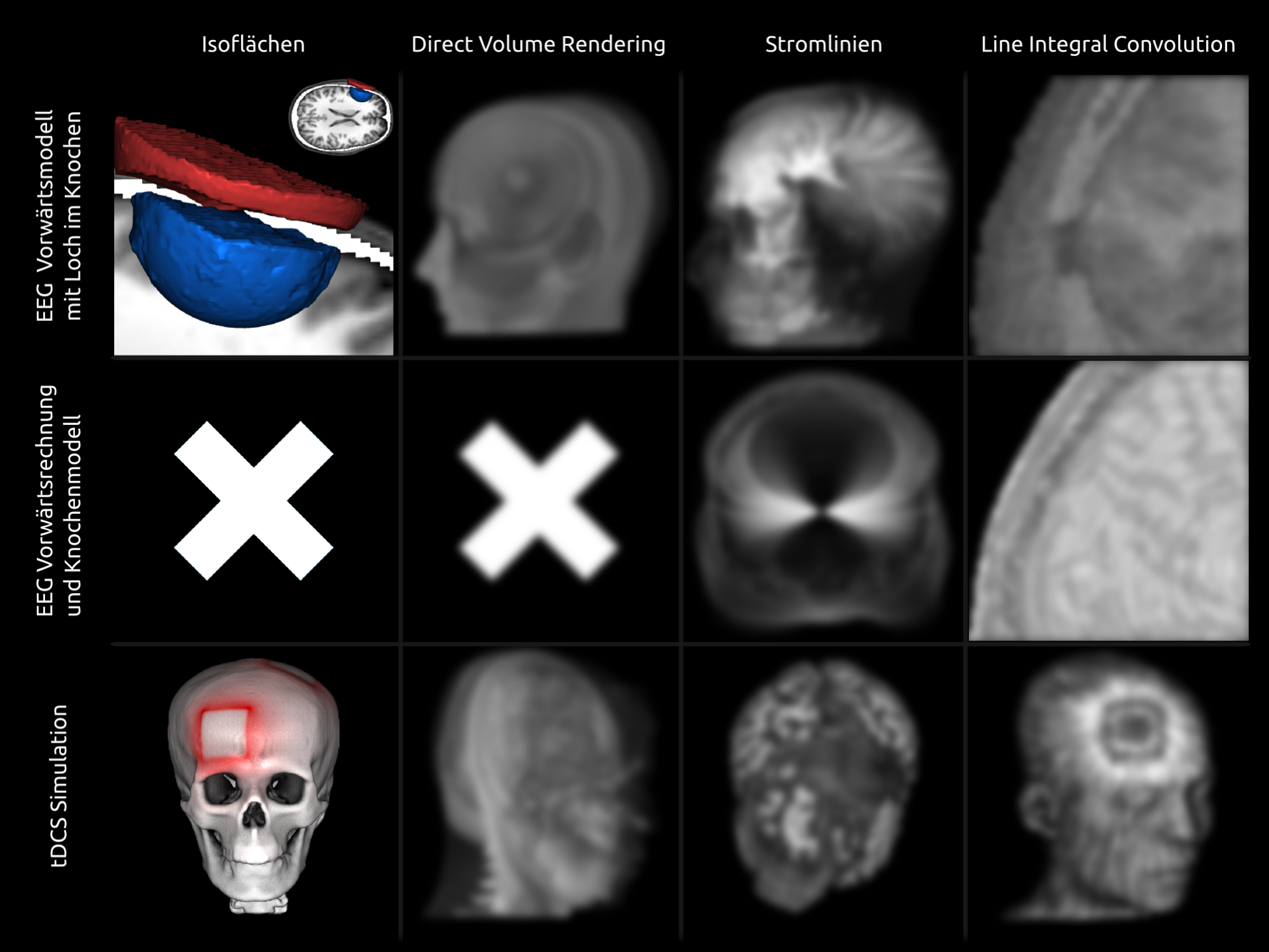
EEG Vorwärtsmodell mit Loch im Knochen				
EEG Vorwärtsrechnung und Knochenmodell	✗	✗		
tDCS Simulation				

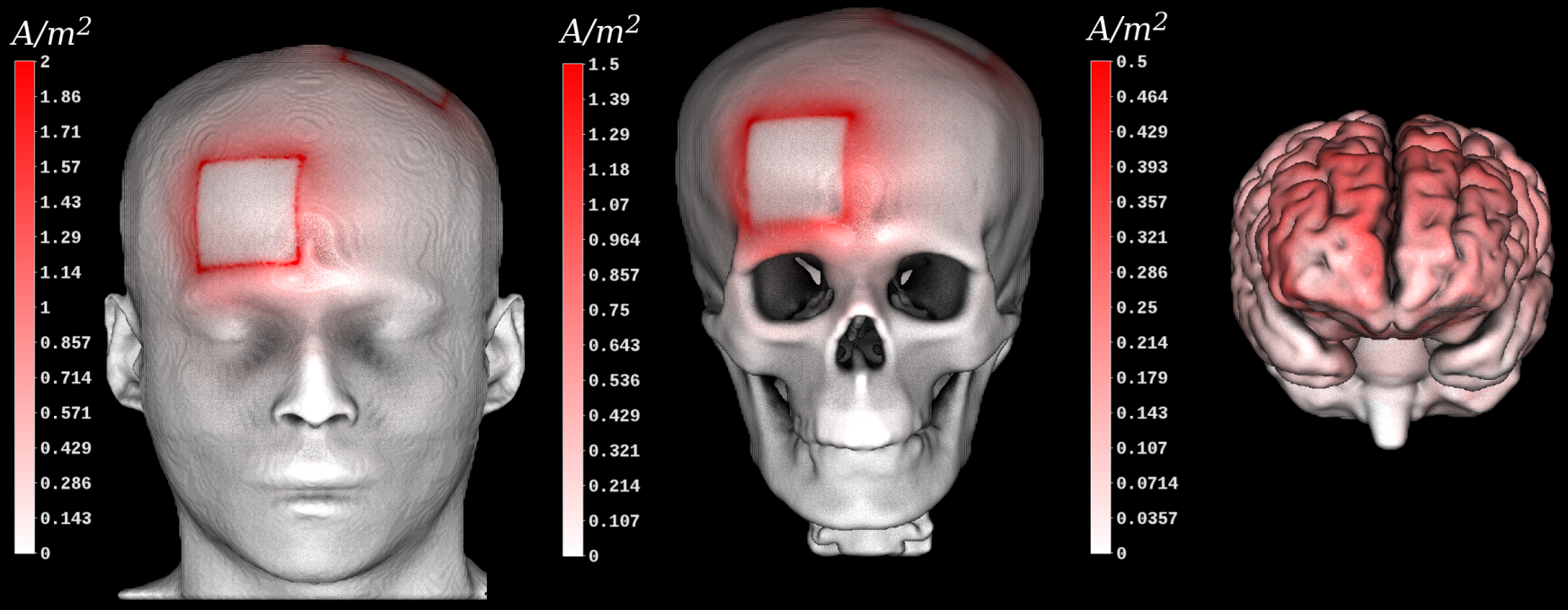


Fokus: Anwendung und Analyse

- S. EICHELBAUM, M. DANNHAUER, M. HLAWITSCHKA, D. BROOKS, T. R. KNÖSCHE, and G. SCHEUERMANN. Visualizing Simulated Electrical Fields from Electroencephalography and Transcranial Electric Brain Stimulation: A Comparative Evaluation. NeuroImage. Vol 101, 2014, 513 - 530.
- S. EICHELBAUM, M. DANNHAUER, G. SCHEUERMANN, D. BROOKS, T. R. KNÖSCHE, and M. HLAWITSCHKA. A Comparative Evaluation of Electrical Field Visualization from EEG/tDCS. HBM 2014, Poster 3029.

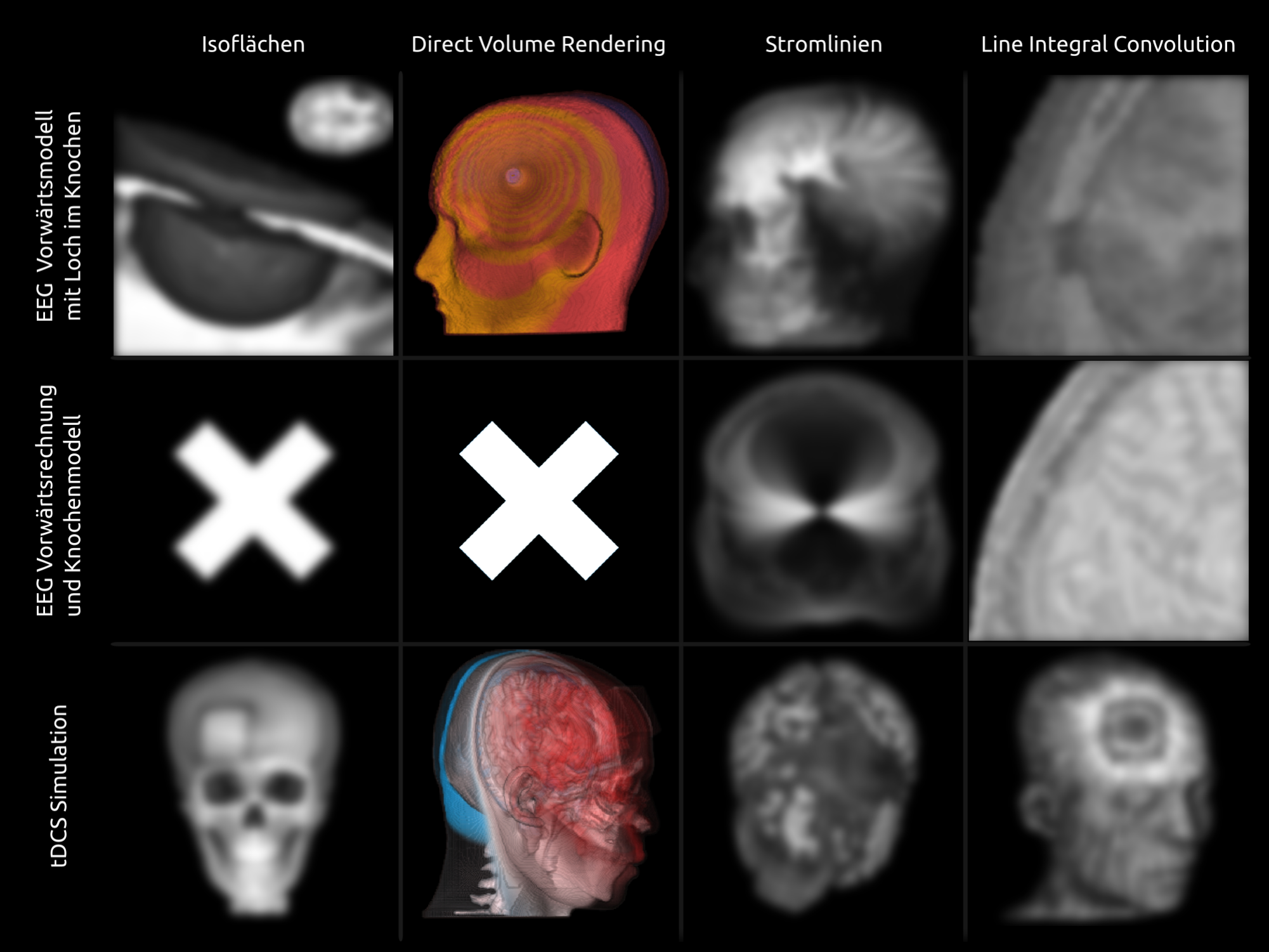
	Isoflächen	Direct Volume Rendering	Stromlinien	Line Integral Convolution
EEG Vorwärtsmodell mit Loch im Knochen				
EEG Vorwärtsrechnung und Knochenmodell	✗	✗		
tDCS Simulation				


Isoflächen
Direct Volume Rendering
Stromlinien
Line Integral Convolution
EEG Vorwärtsmodell mit Loch im Knochen
EEG Vorwärtsrechnung und Knochenmodell
tDCS Simulation



Isoflächen: am Beispiel tDCS

- \+ Leichtes einbetten von Kontext
- – Zeigt nur Teil der Daten


Isoflächen
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Stromlinien
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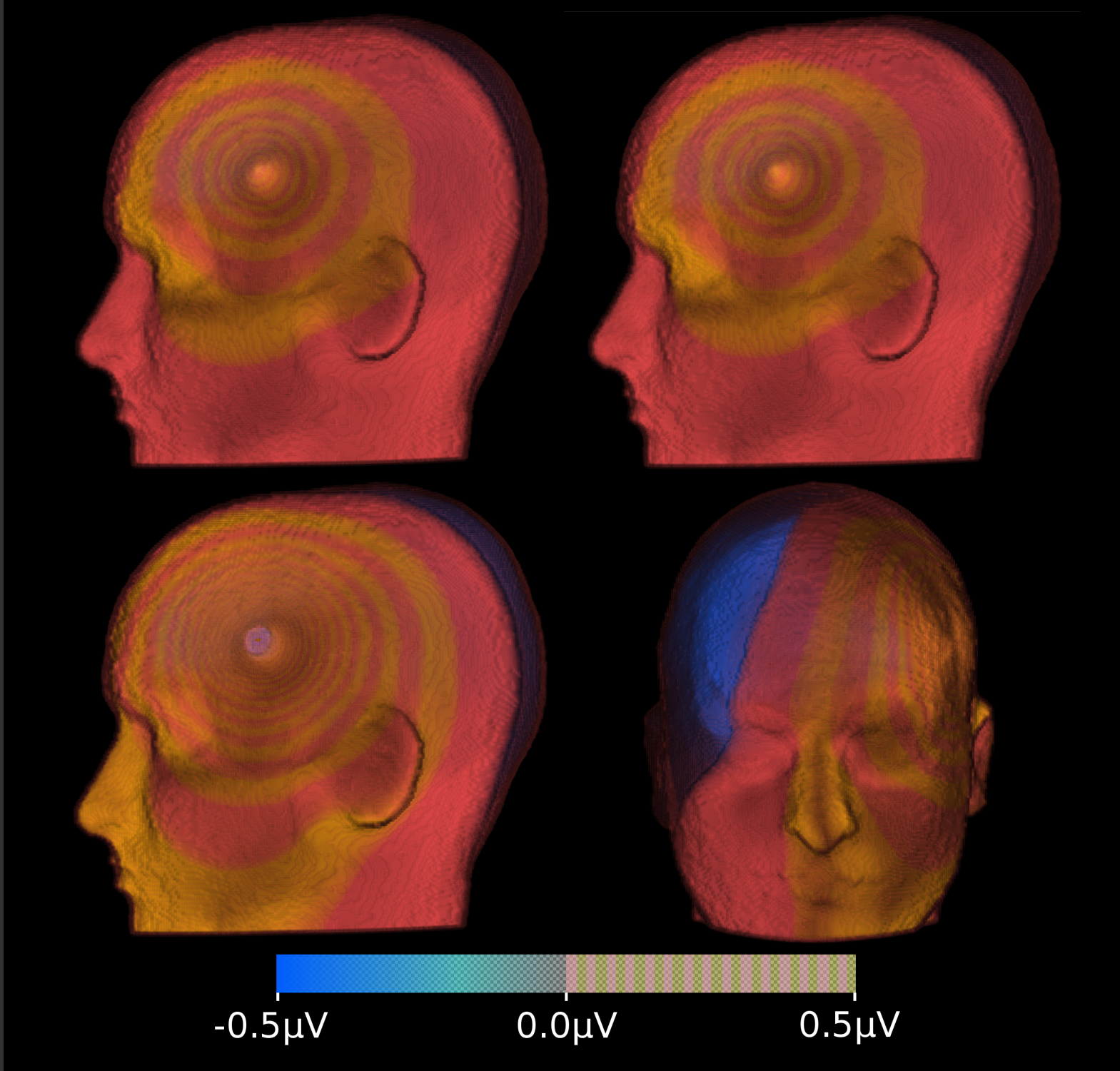
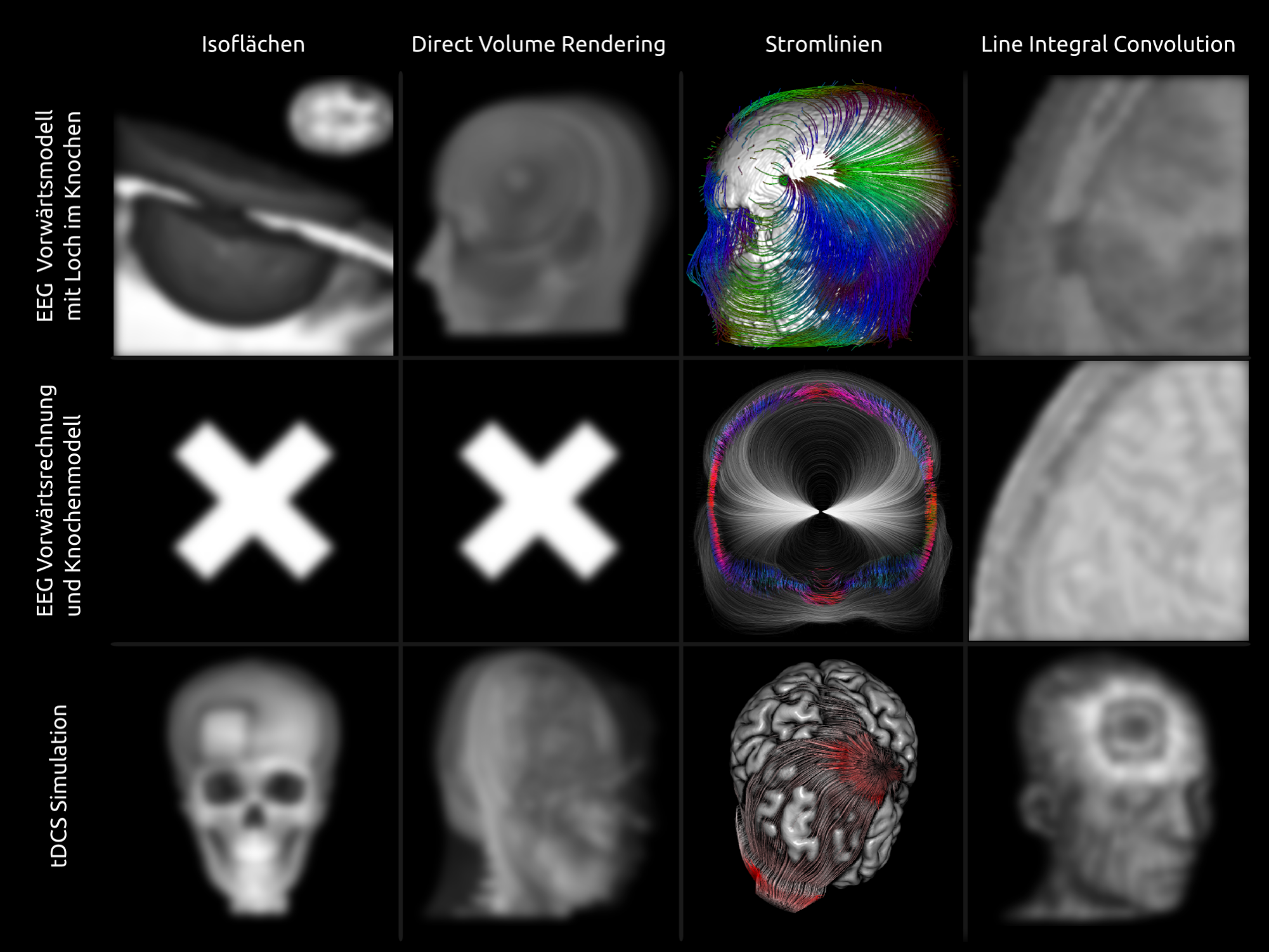
EEG Vorwärtsmodell mit Loch im Knochen
EEG Vorwärtsrechnung und Knochenmodell
tDCS Simulation

DVR: Lochmodell

- + Räumliche Verteilung, Schachtelung
- – Anatomischer Kontext?
- – Design der Transfer-funktion komplex




Isoflächen
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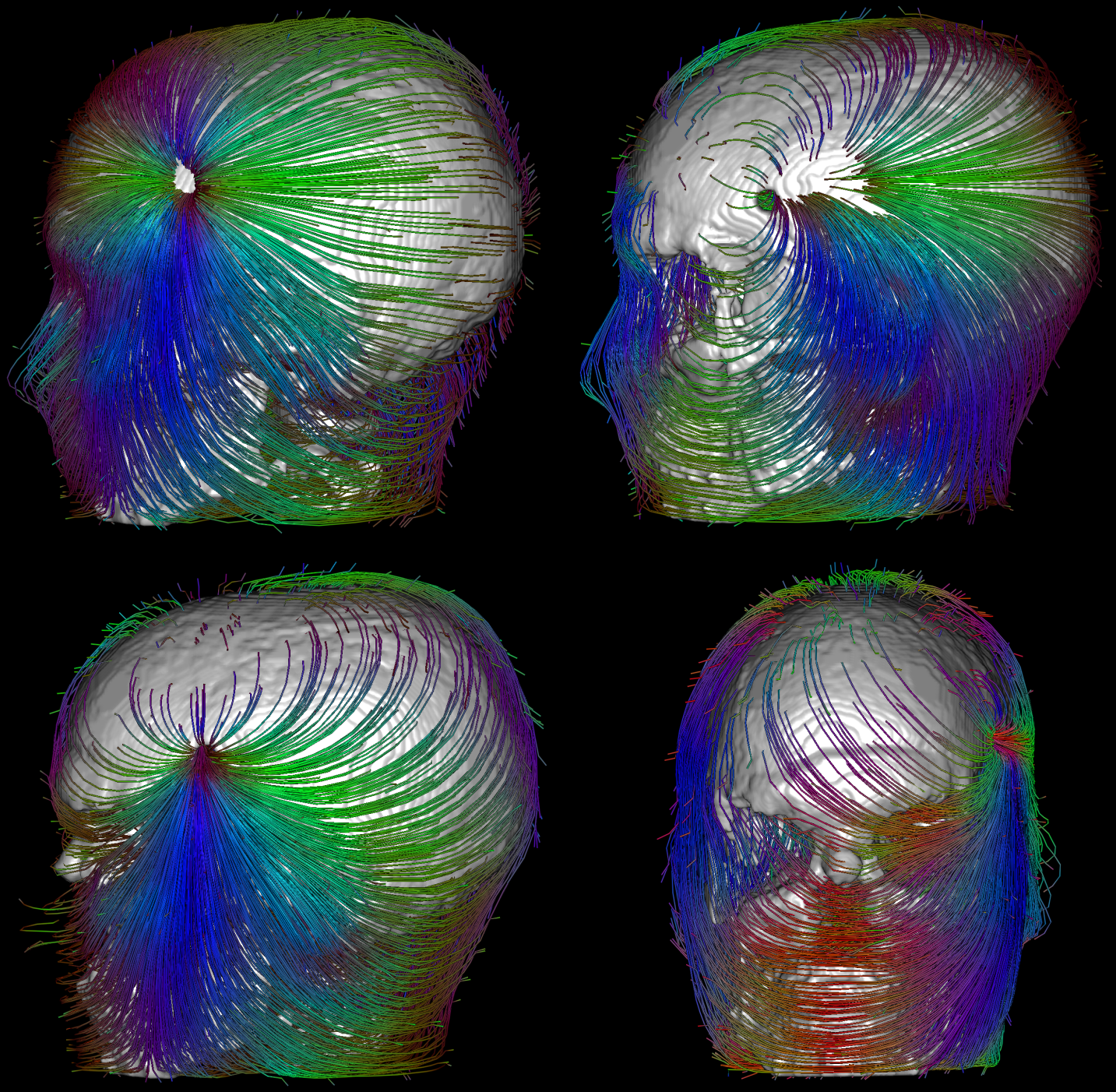
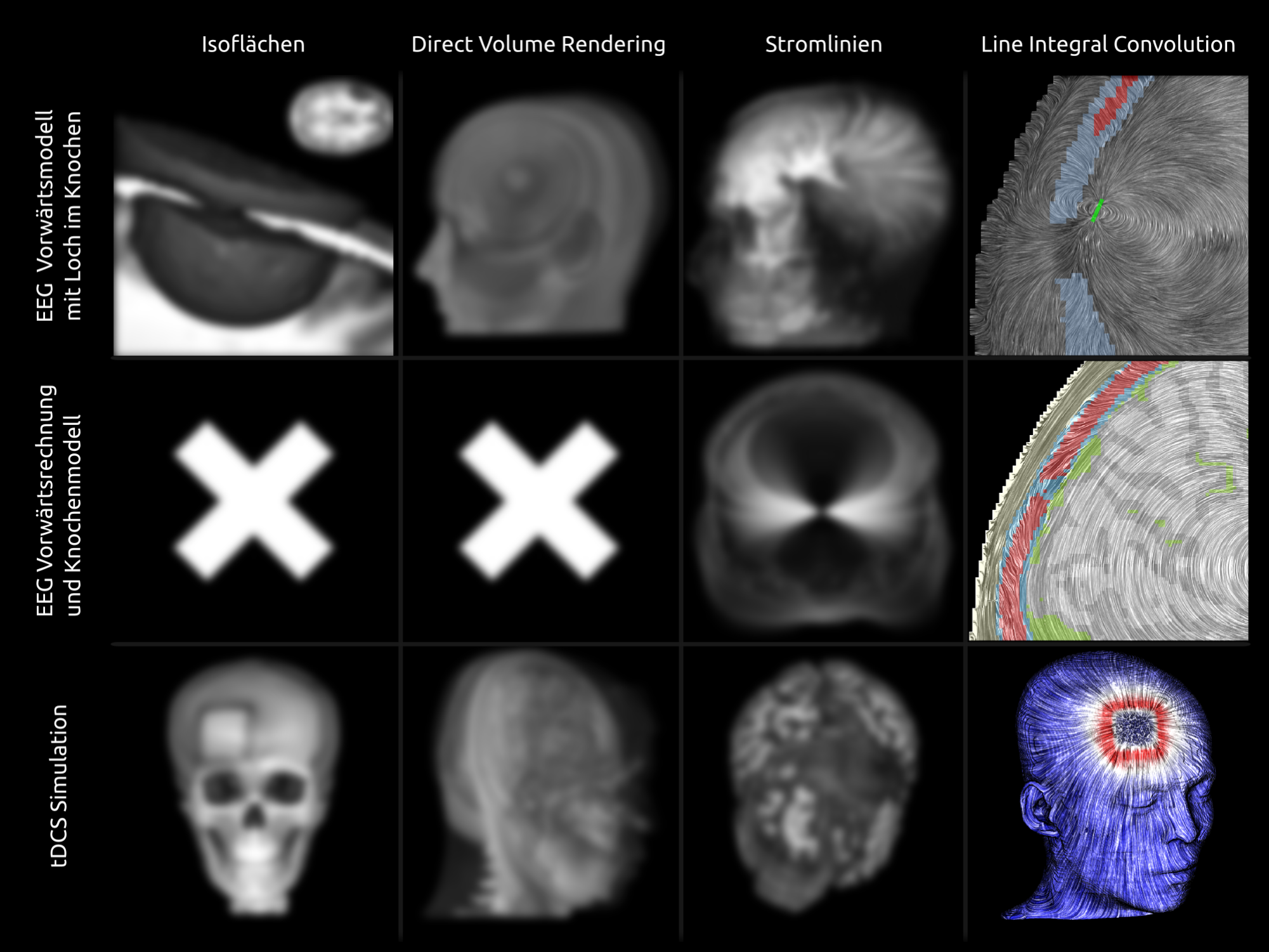
Stromlinien
Line Integral Convolution
EEG Vorwärtsmodell mit Loch im Knochen
EEG Vorwärtsrechnung und Knochenmodell
tDCS Simulation

DVR: Lochmodell

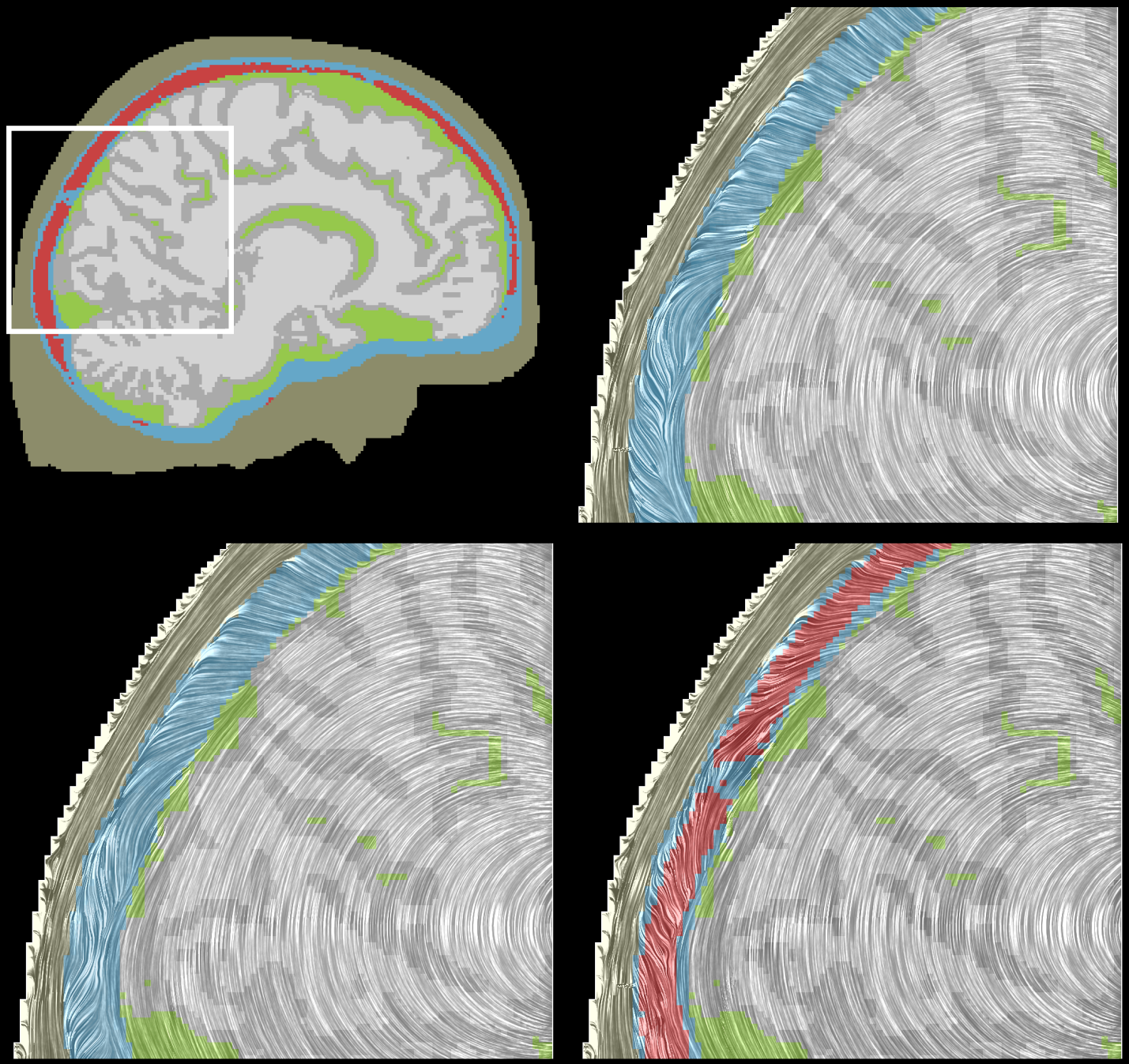
- + Globale, gerichtete Information in 3D
- – Überdeckung
- – Vorberechnung

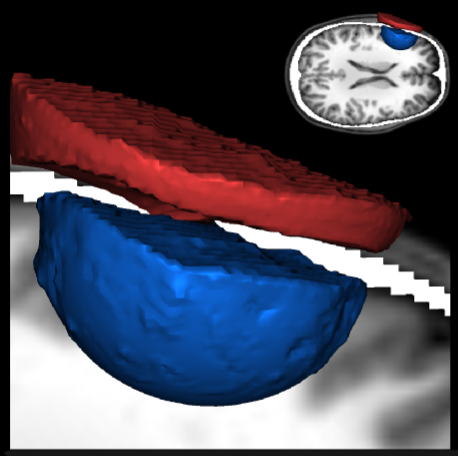
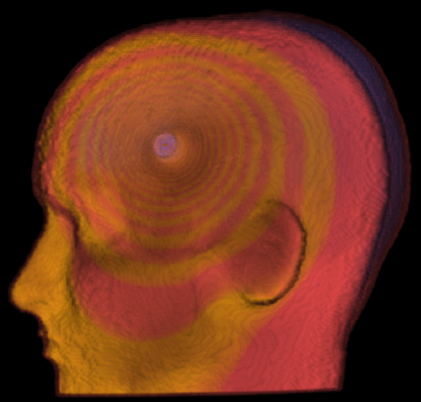
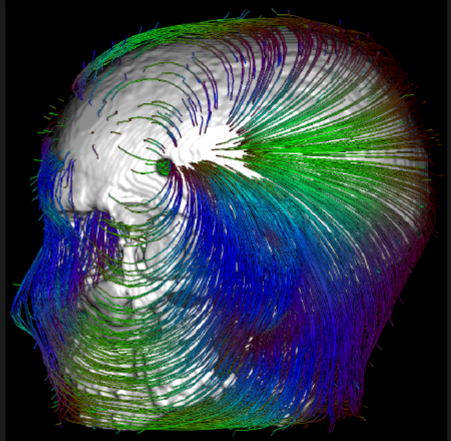
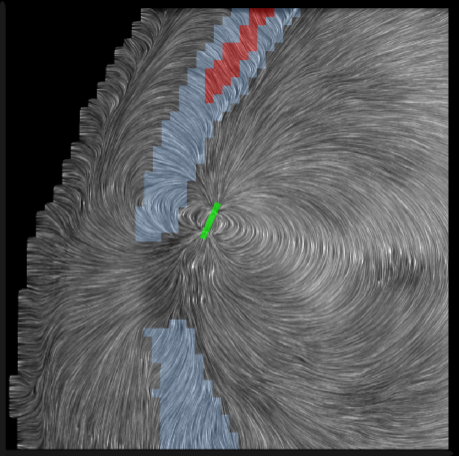
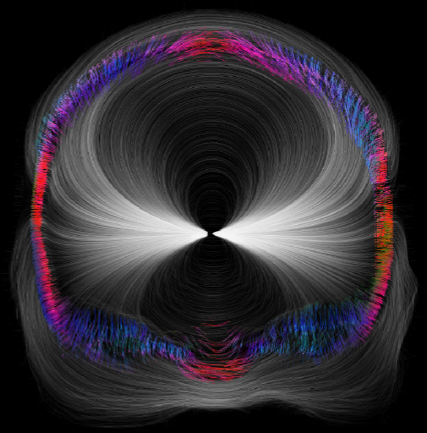
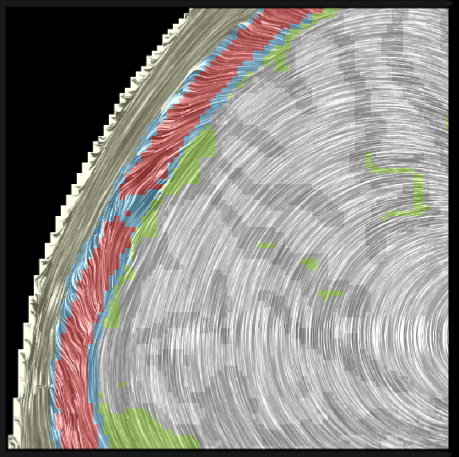
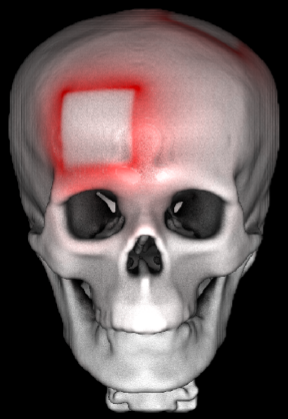
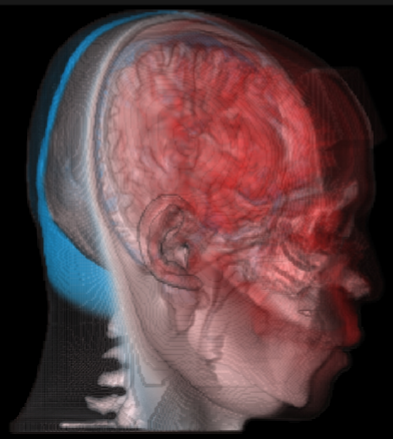
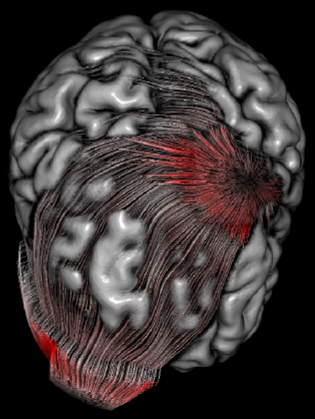
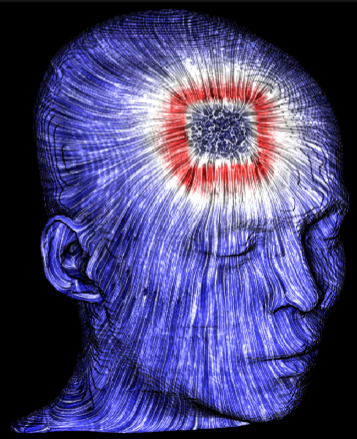


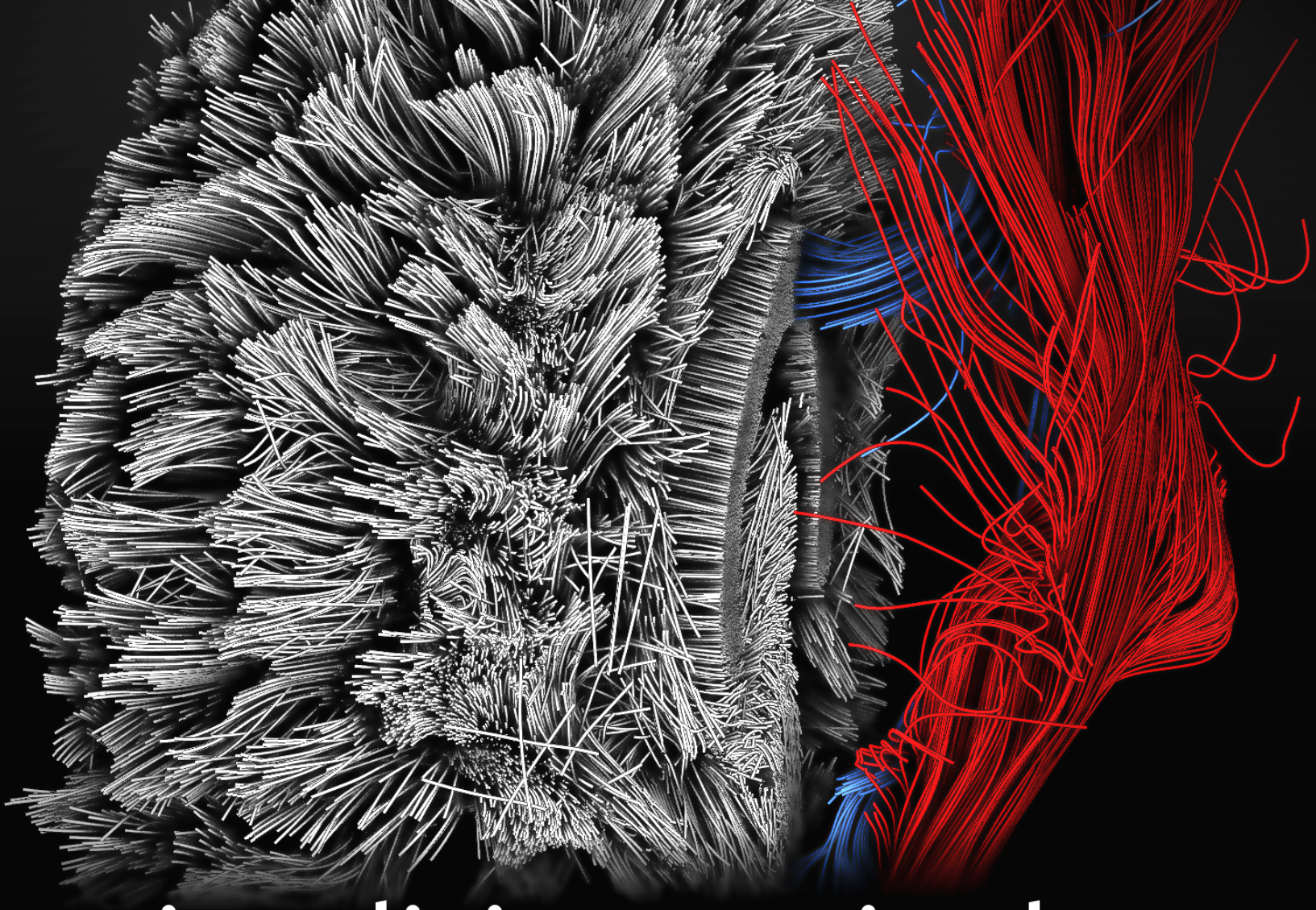

Isoflächen
Direct Volume Rendering
Stromlinien
Line Integral Convolution
EEG Vorwärtsmodell mit Loch im Knochen
EEG Vorwärtsrechnung und Knochenmodell
tDCS Simulation

DVR: Knochen-modellierung

- + Lokale, gerichtete Information
- + Qualitative Vergleichbarkeit
- – Quantifizierung
- – Kombination mit Colormaps problematisch



	Isoflächen	Direct Volume Rendering	Stromlinien	Line Integral Convolution
EEG Vorwärtsmodell mit Loch im Knochen				
EEG Vorwärtsrechnung und Knochenmodell	✗	✗		
tDCS Simulation				

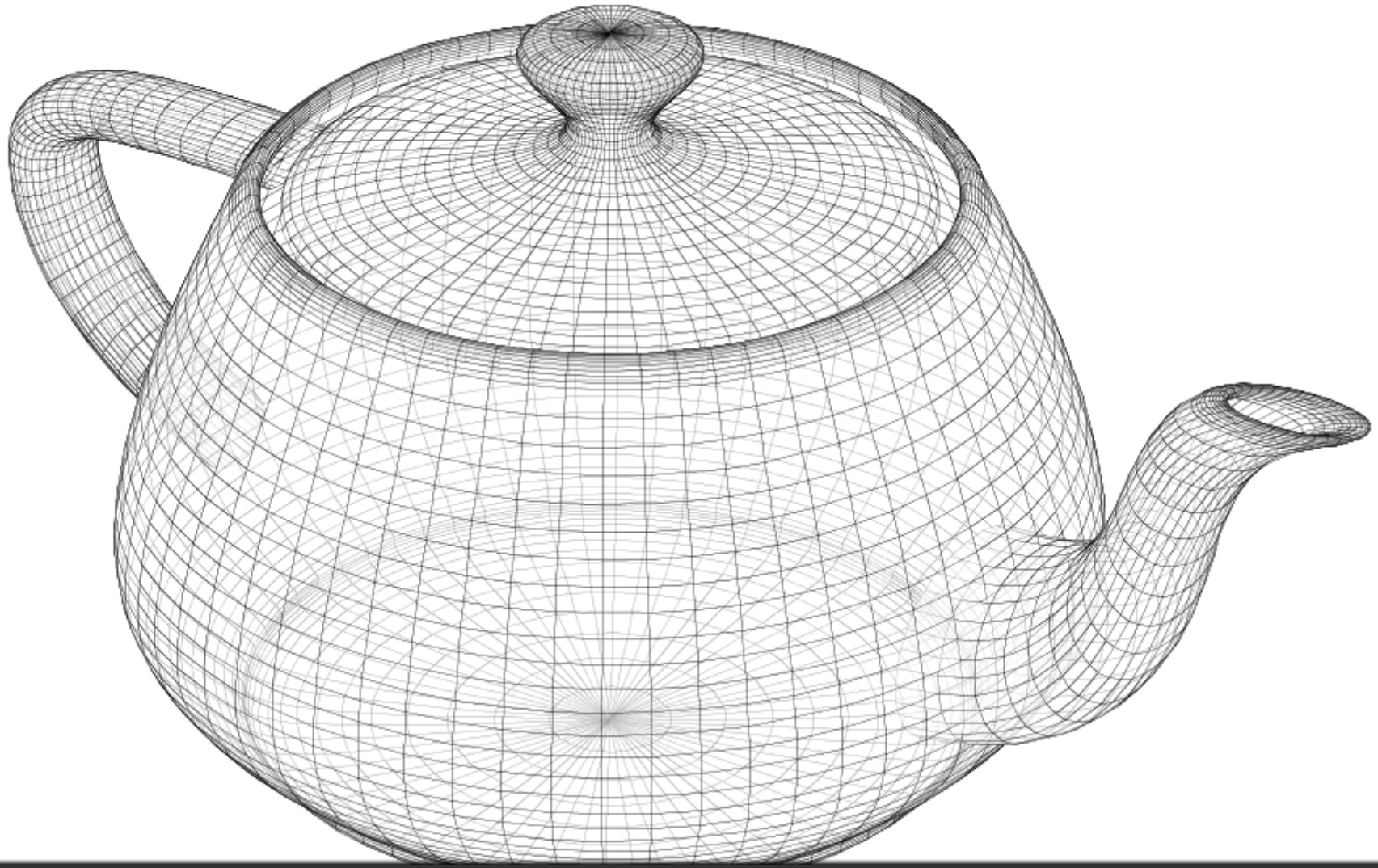


Teil 1

Visualisierung in den Neurowissenschaften

Teil 2

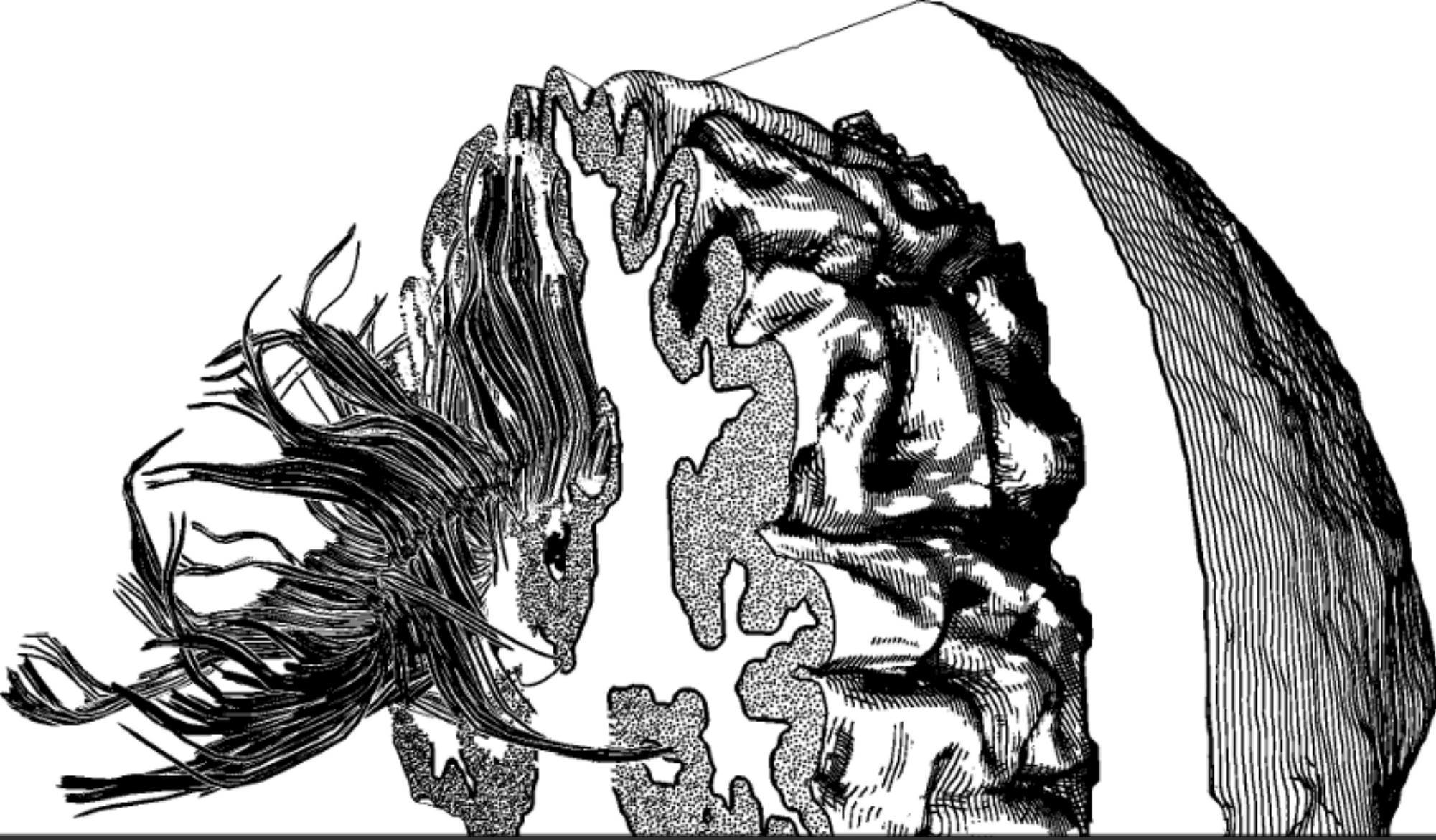
Computergrafik in der Visualisierung



Gerastert: Richard Hull, 2014

github.com/rm-hull/wireframes

Physikalisch: Turkish Tea And A Teapot v3, »the-panther«
the-panther.deviantart.com/art/Turkish-Tea-And-A-Teapot-v-3-1842192



Illustrativ: Svetachov et al., 2010

Medizinische Bildaten des Menschen im Zusammenhang illustriert.

Realistisch: Direct Volume Rendering: Kronander et al., 2011

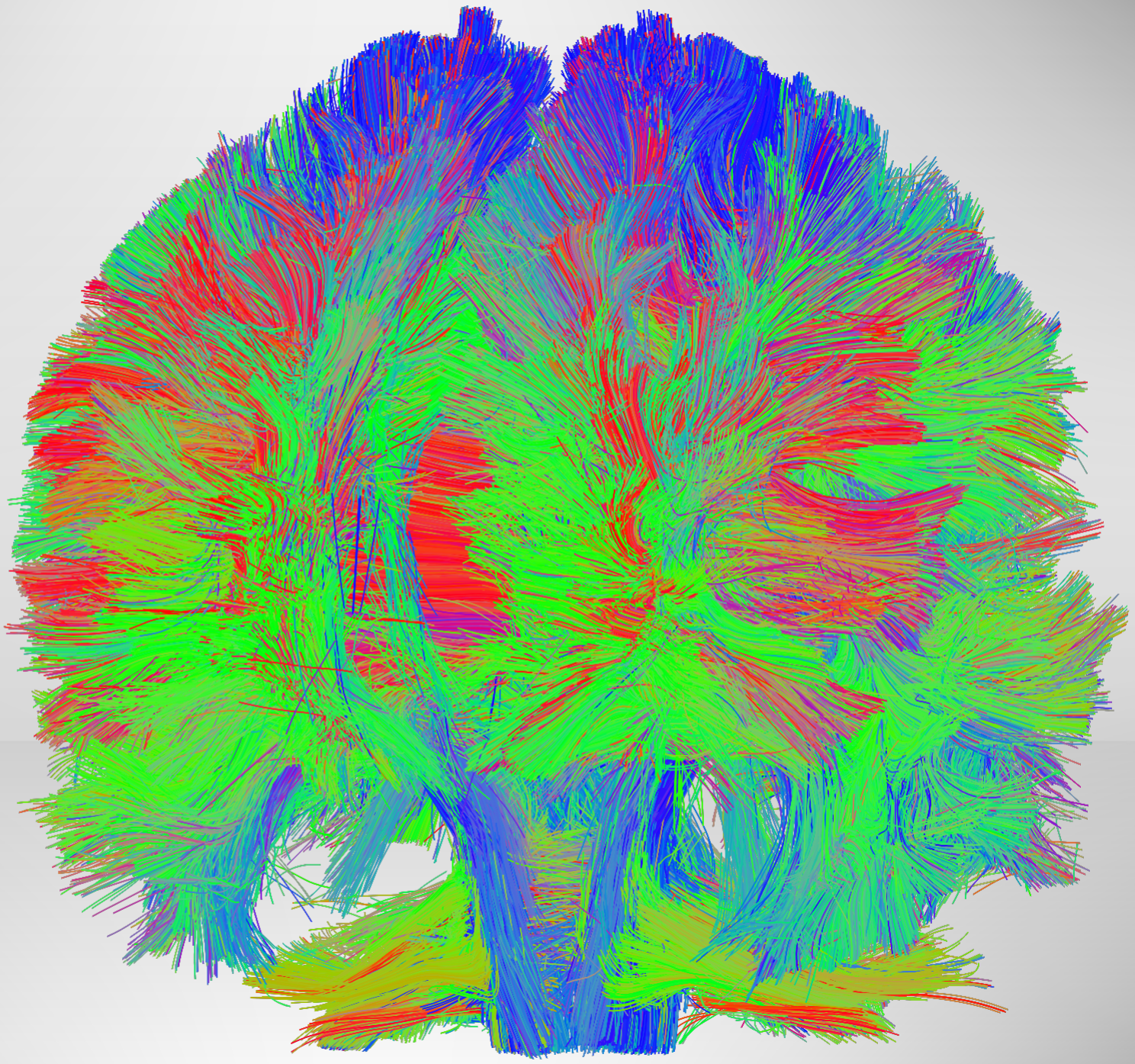
Computertomographie als Volumen dargestellt. Besondere Hervorhebung des Schädels.

Teil 2

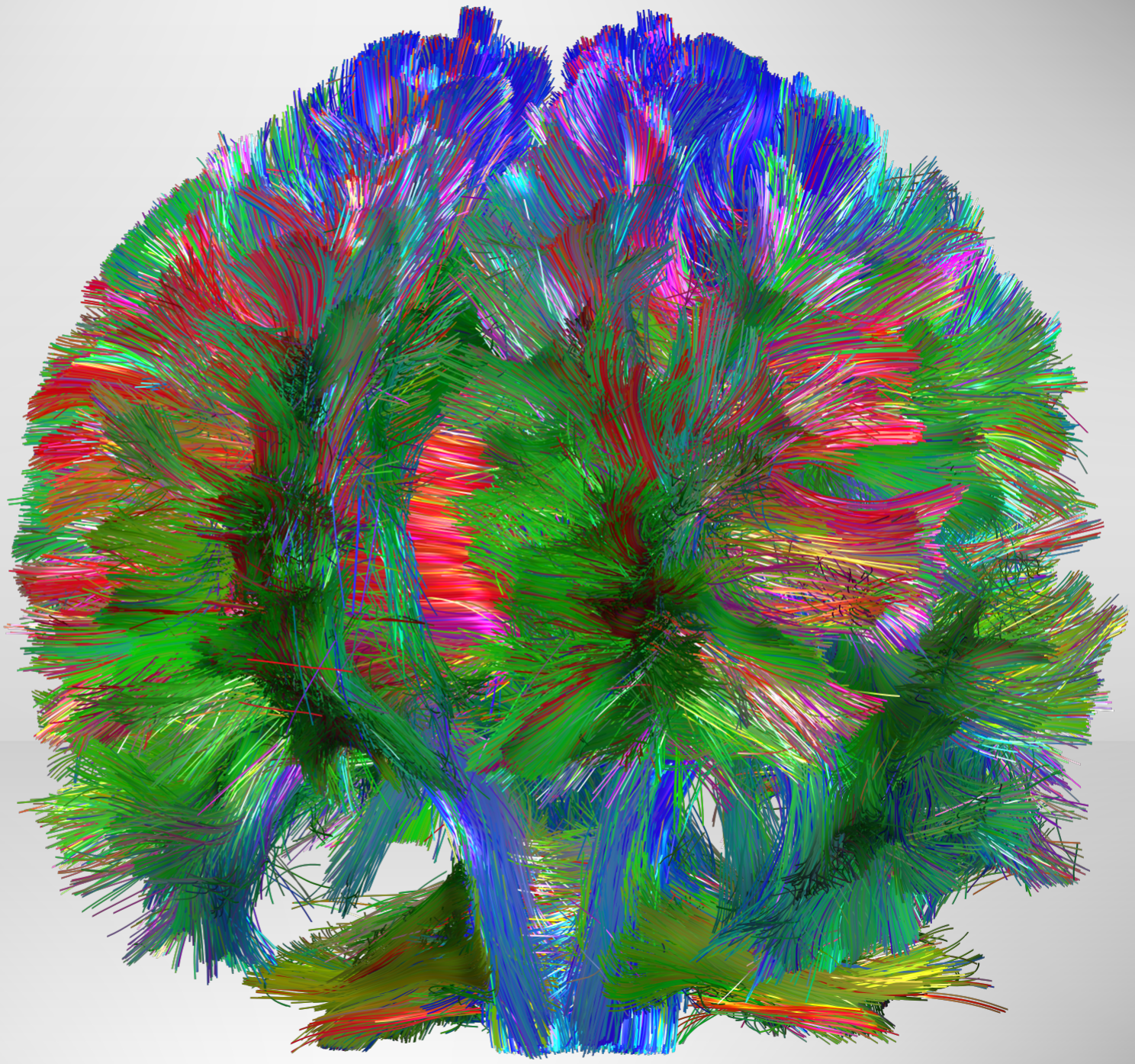
Computergrafik in der Visualisierung

Falschfarben: räumliche oder strukturellen Information?

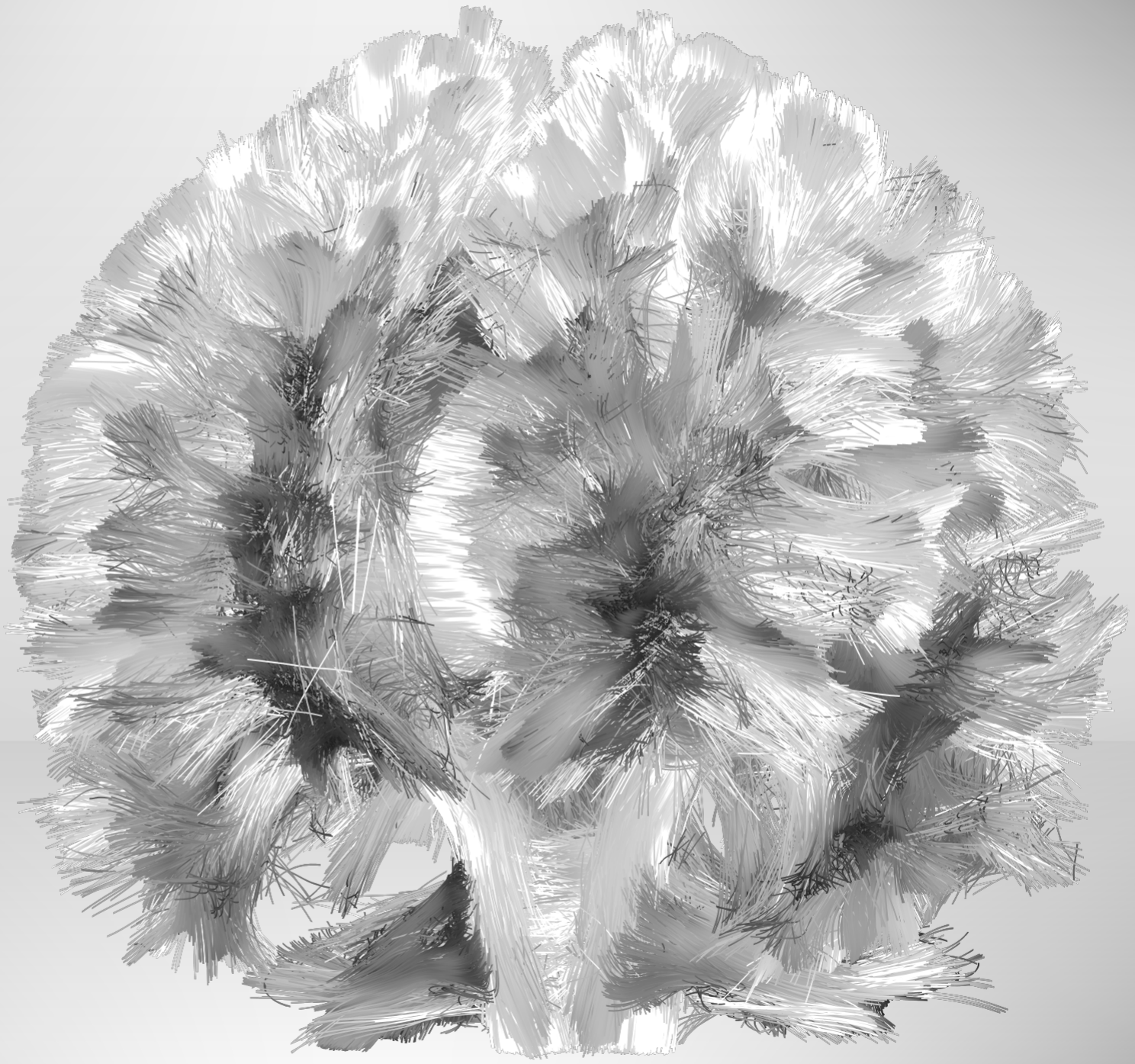
75.000 Nervenfasern im Gehirn, welche durch Linien repräsentiert werden. Die Farbe beschreibt die Hauptrichtung der Faser (grün: vorne-hinten, rot: links-rechts, blau: oben-unten).



+ **Lokale Beleuchtung**: lokale, strukturelle Information



Lokale Beleuchtung: lokale, strukturelle Information



Realistisch: Direct Volume Rendering: Kronander et al., 2011

Crytek Engine SSAO: weiche globale Schattierung, (Mittring, 2007)

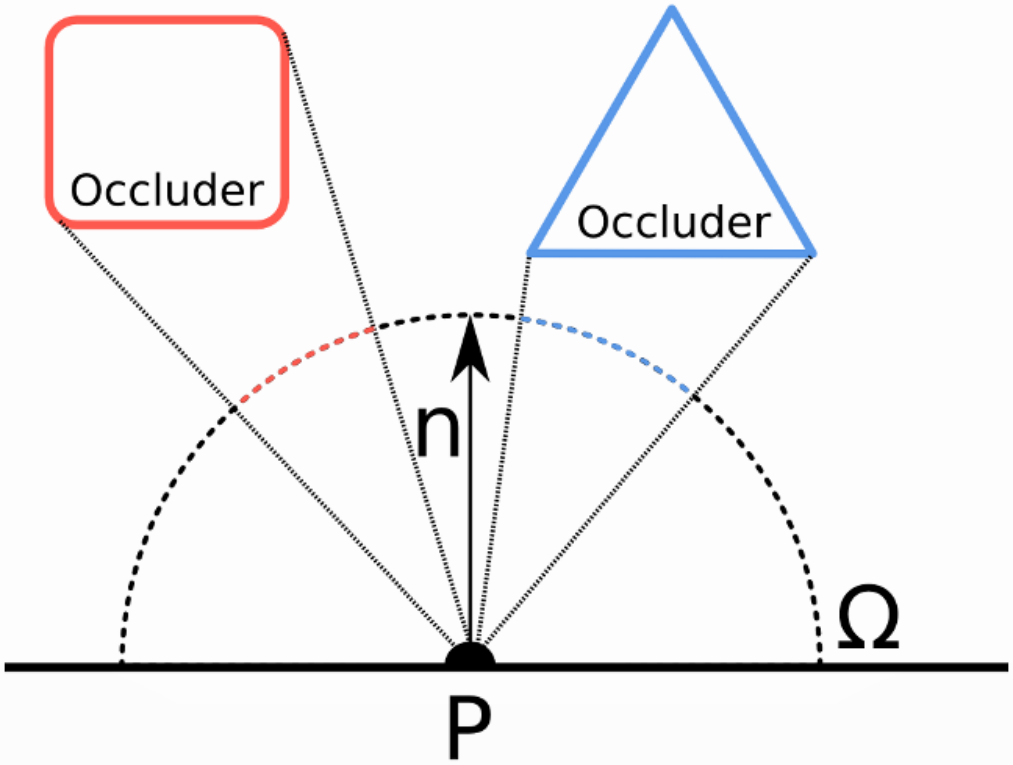
Globale Schattierung, SSAO: einfache räumliche Information

Globale Schattierung, LineAO:
Plastizität und Struktur

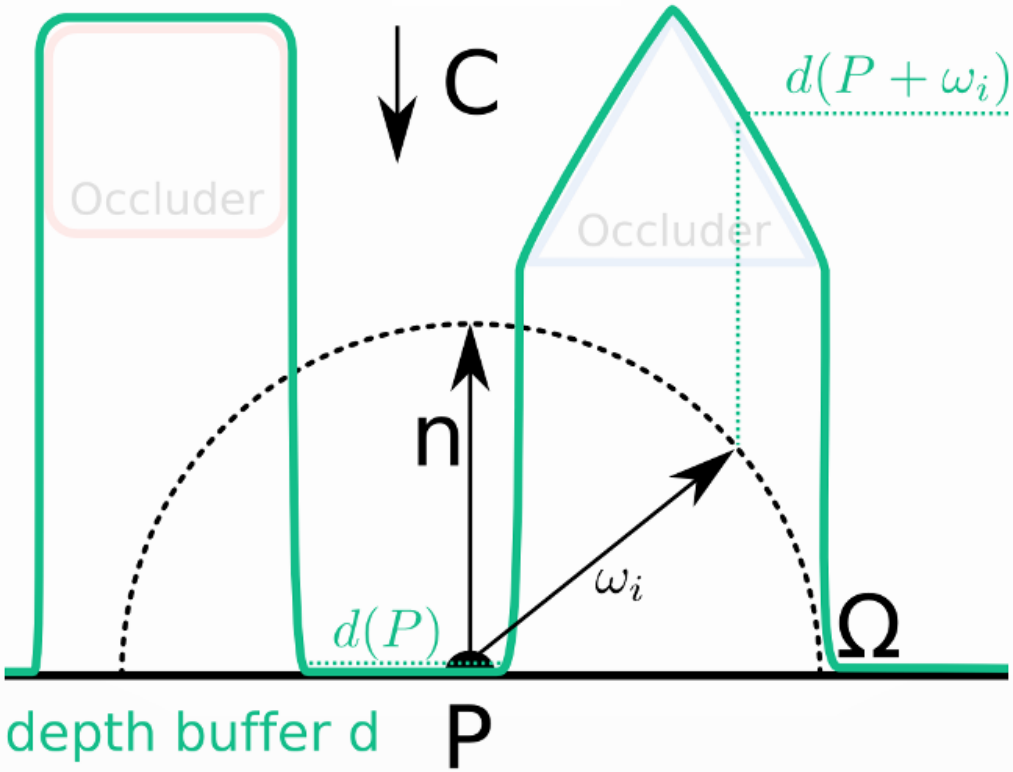
Globale Schattierung, LineAO: Plastizität und Struktur, 40 FPS, konstanter Laufzeitover-head

Publikation:

- S. EICHELBAUM, M. HLAWITSCHKA, and G. SCHEUERMANN. LineAO – Improved Three-Dimensional Line Rendering. IEEE TVCG 19.3 (2013), 433-445



Ambient Occlusion: Abschwächung des Umgebungslichts



Screen Space Ambient Occlusion:
Transfer des Problems in den Bildraum.

Tiefenbuffer als Höhenfeld: Gebirgslandschaft,
Normalen bei Linien? Siehe: Mallo et al. 2005.

Tiefenbuffer:
Tiefe jedes
Pixels zur
Bildebene.

Globale Schattierung, SSAO: einfache räumliche Information

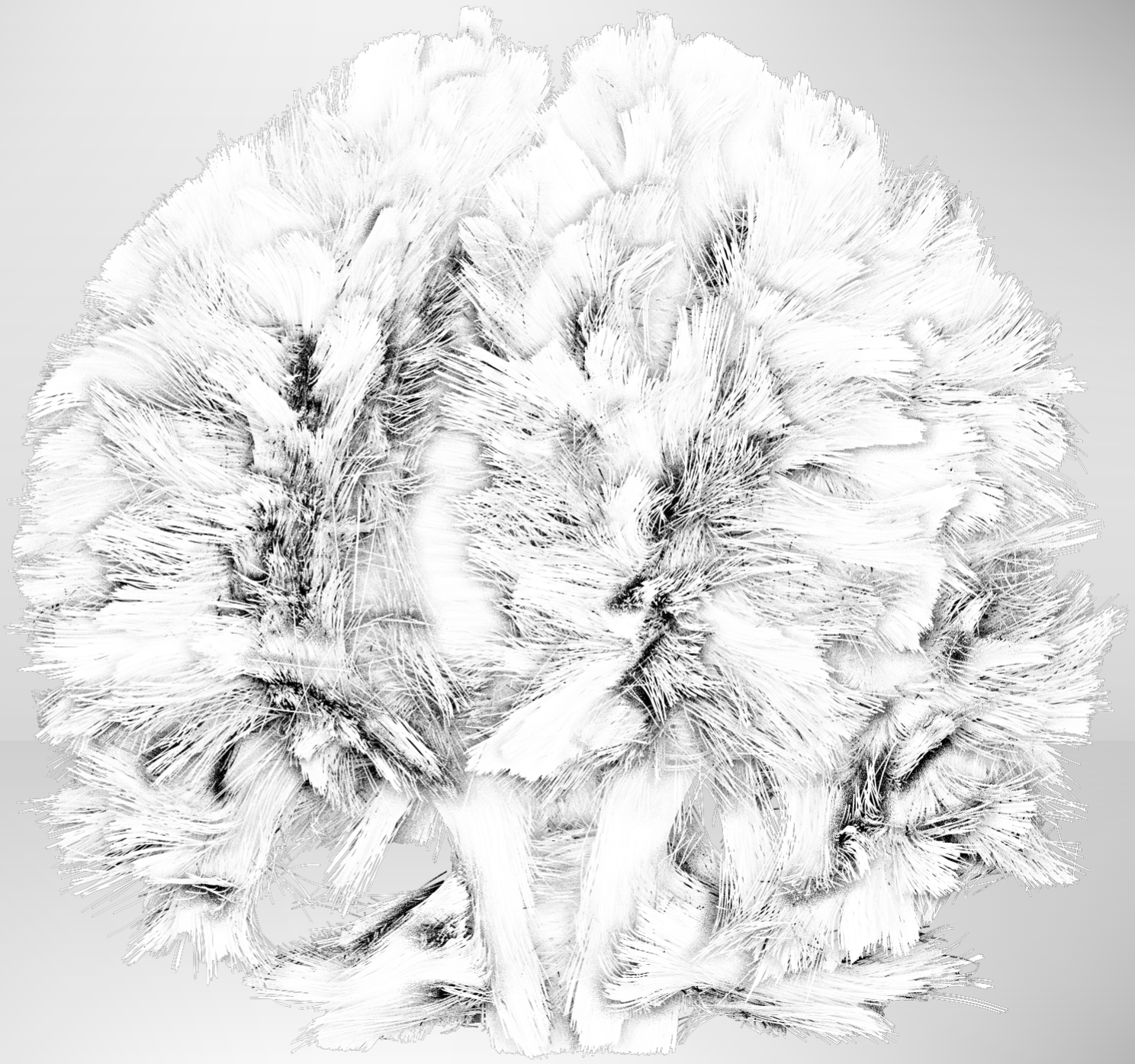
$r = 1$

Globale Schattierung, SSAO: einfache räumliche Information

$r = 2$

Globale Schattierung, SSAO: einfache räumliche Information

$r = 5$

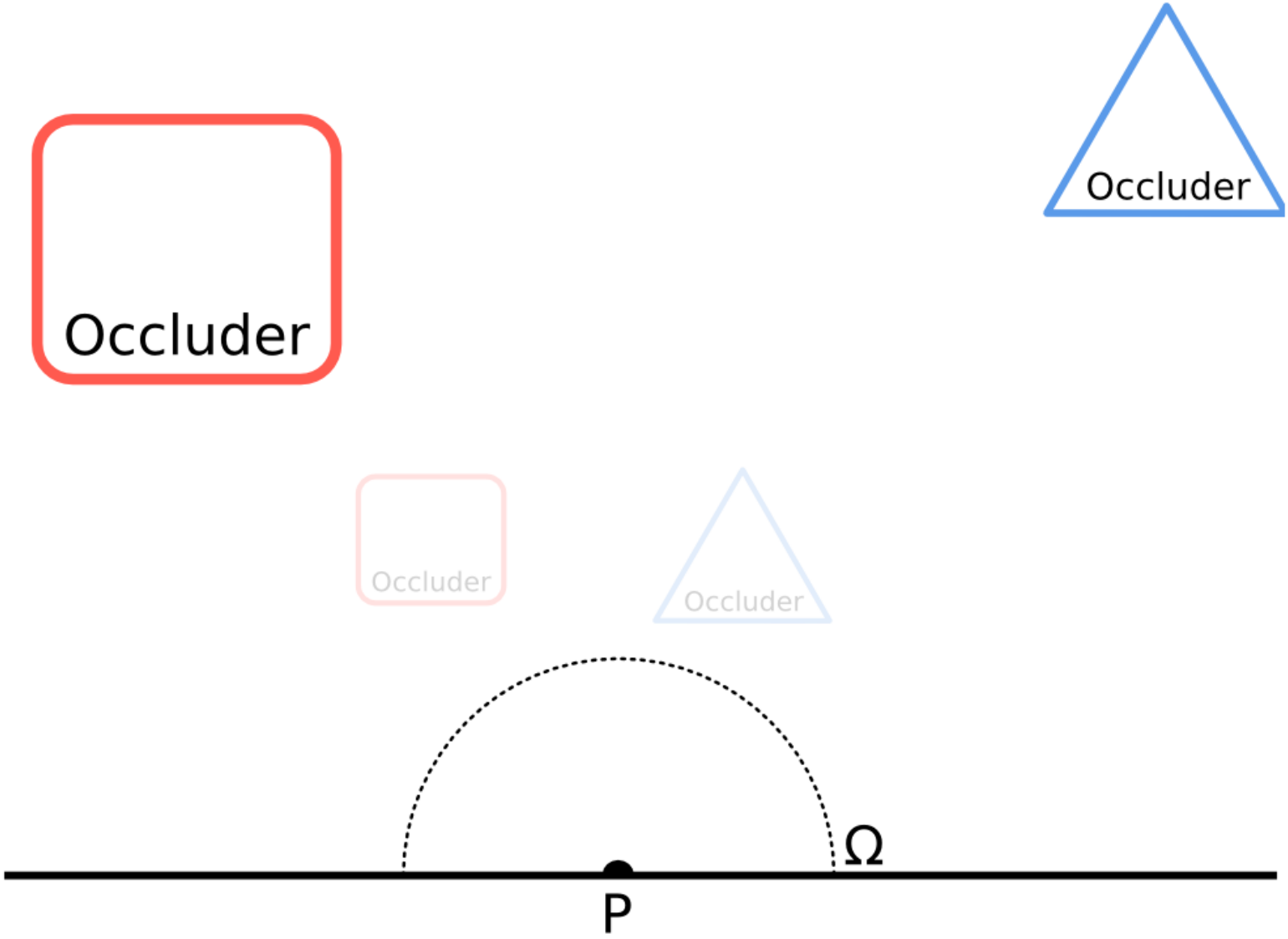


Globale Schattierung, SSAO: einfache räumliche Information

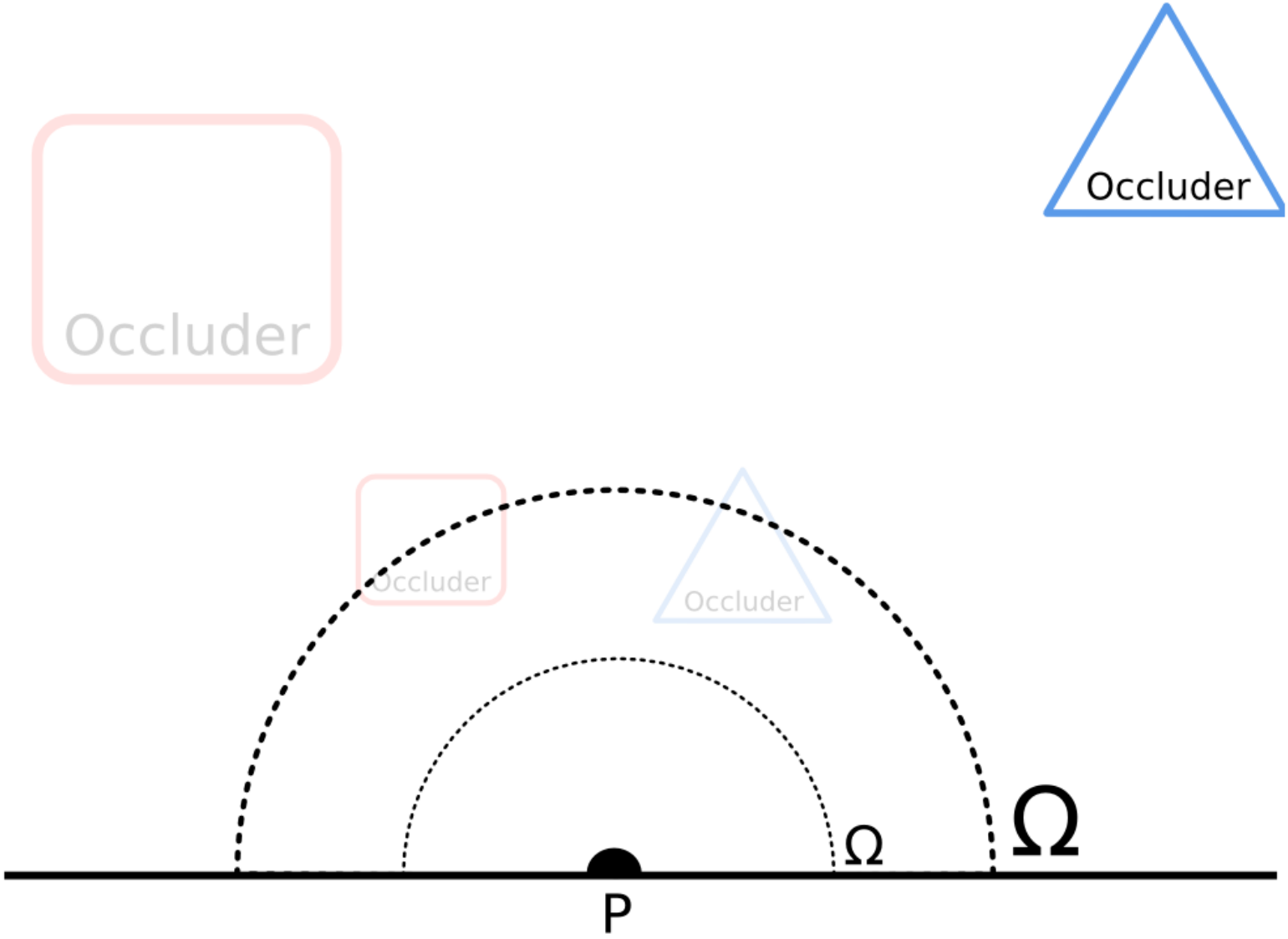
$r = 10$

Globale Schattierung, SSAO: einfache räumliche Information

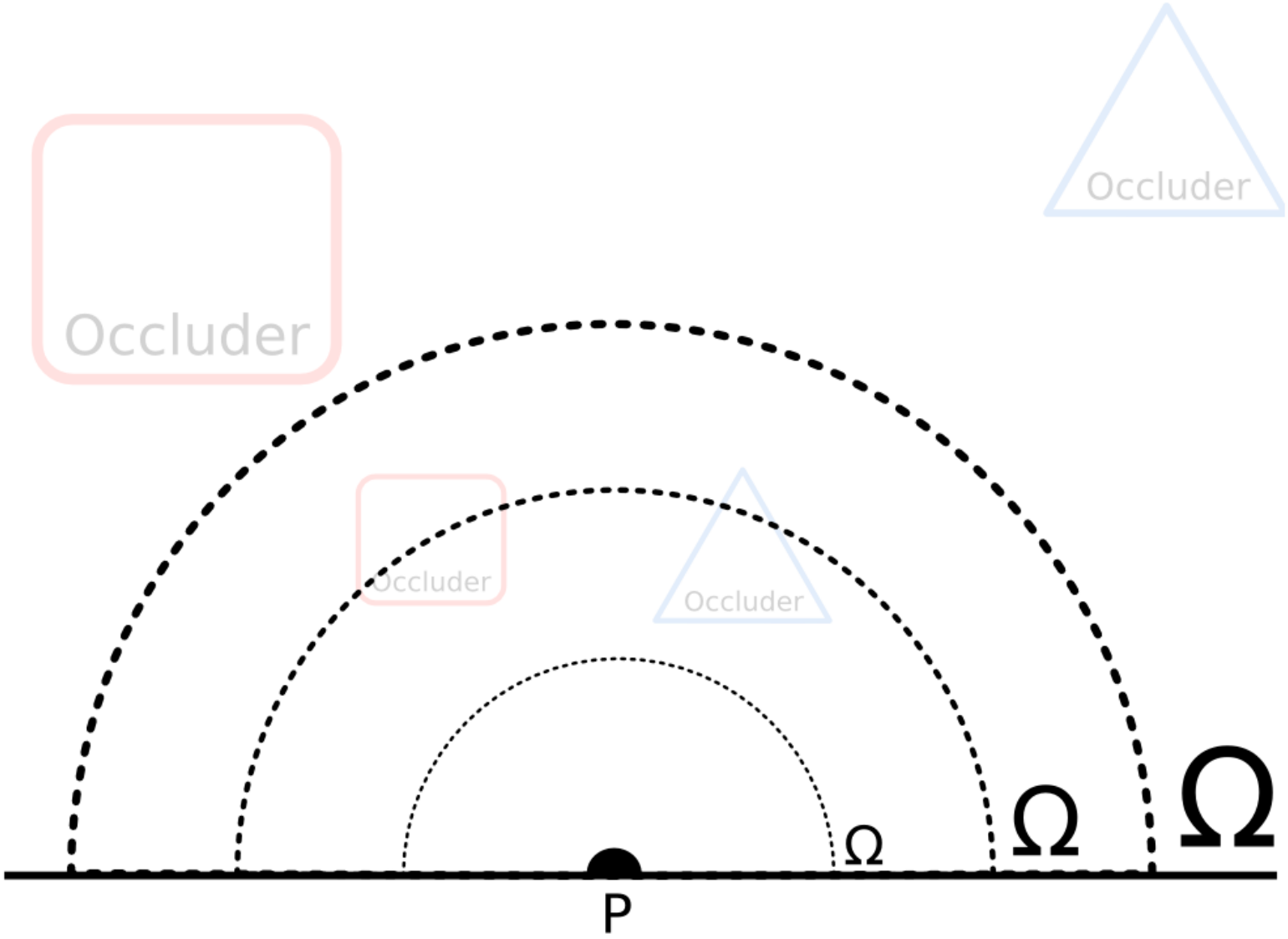
$r = 20$



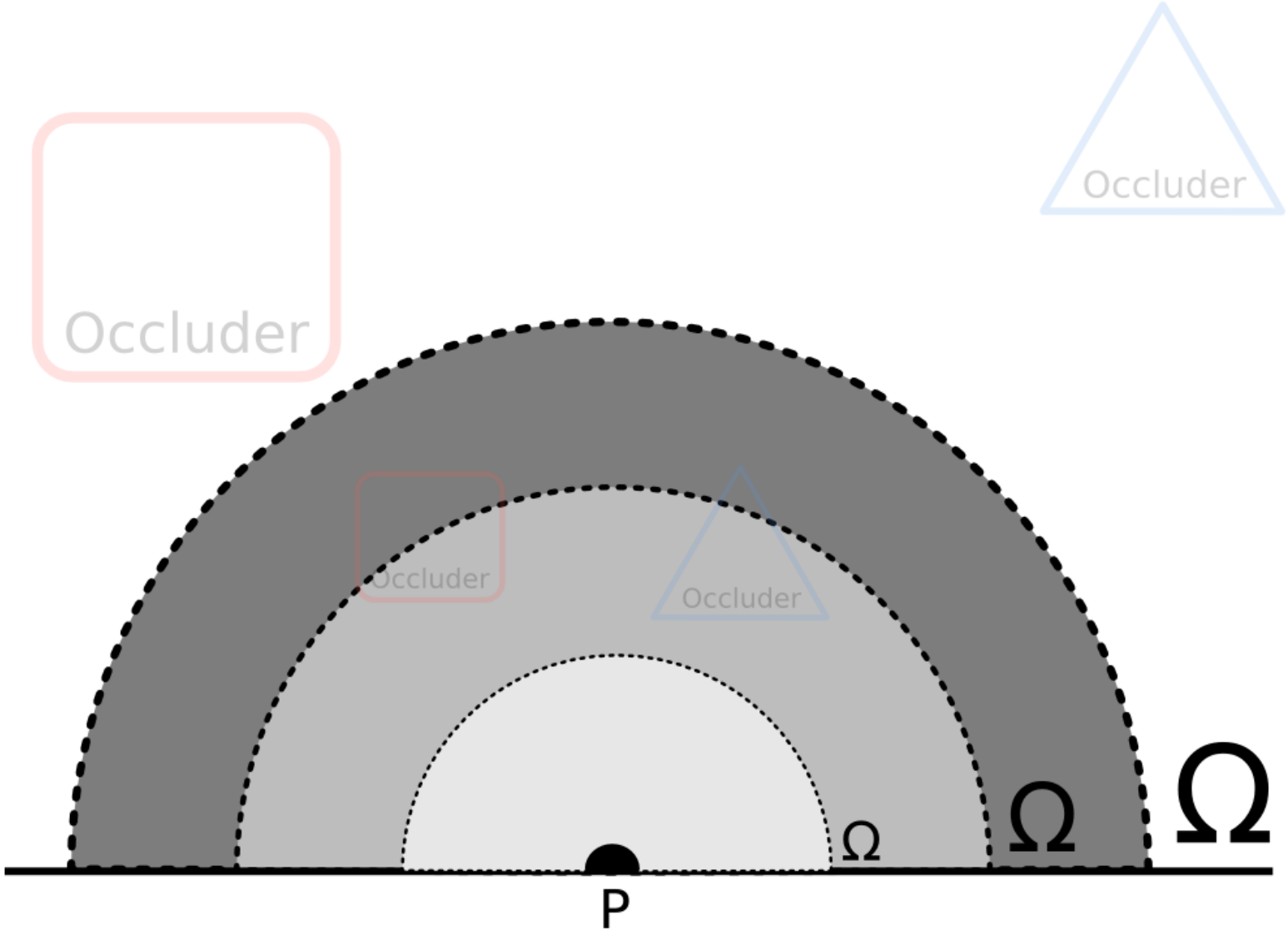
Von SSAO zu LineAO: nahe Occluder ...



Von SSAO zu LineAO: …



Von SSAO zu LineAO: ... ferne Occluder



Gewichtung: Ω, Winkel zur Normalen, Höhe (Tiefenbuffer)

Globale Schattierung, LineAO:
Plastizität und Struktur

Parameter:
Anzahl der
Samplinghalb-
kugeln

$s_r = 3$

Parameter:
Anzahl der
Samplinghalb-
kugeln

$s_r = 1$

Parameter:
Anzahl der
Samplinghalb-
kugeln

$s_r = 3$

Parameter:
Anzahl der
Samplinghalb-
kugeln

$s_r = 8$

Parameter: maximale Anzahl der Samples pro Samplinghalb-kugel

$s_h = 16$

Parameter: maximale Anzahl der Samples pro Samplinghalb-kugel

$s_h = 8$

Parameter: maximale Anzahl der Samples pro Samplinghalb-kugel

$s_h = 1$

Parameter:
kleinster
Samplingradius

$r_0 = 1.5w$

Parameter:
kleinster
Samplingradius

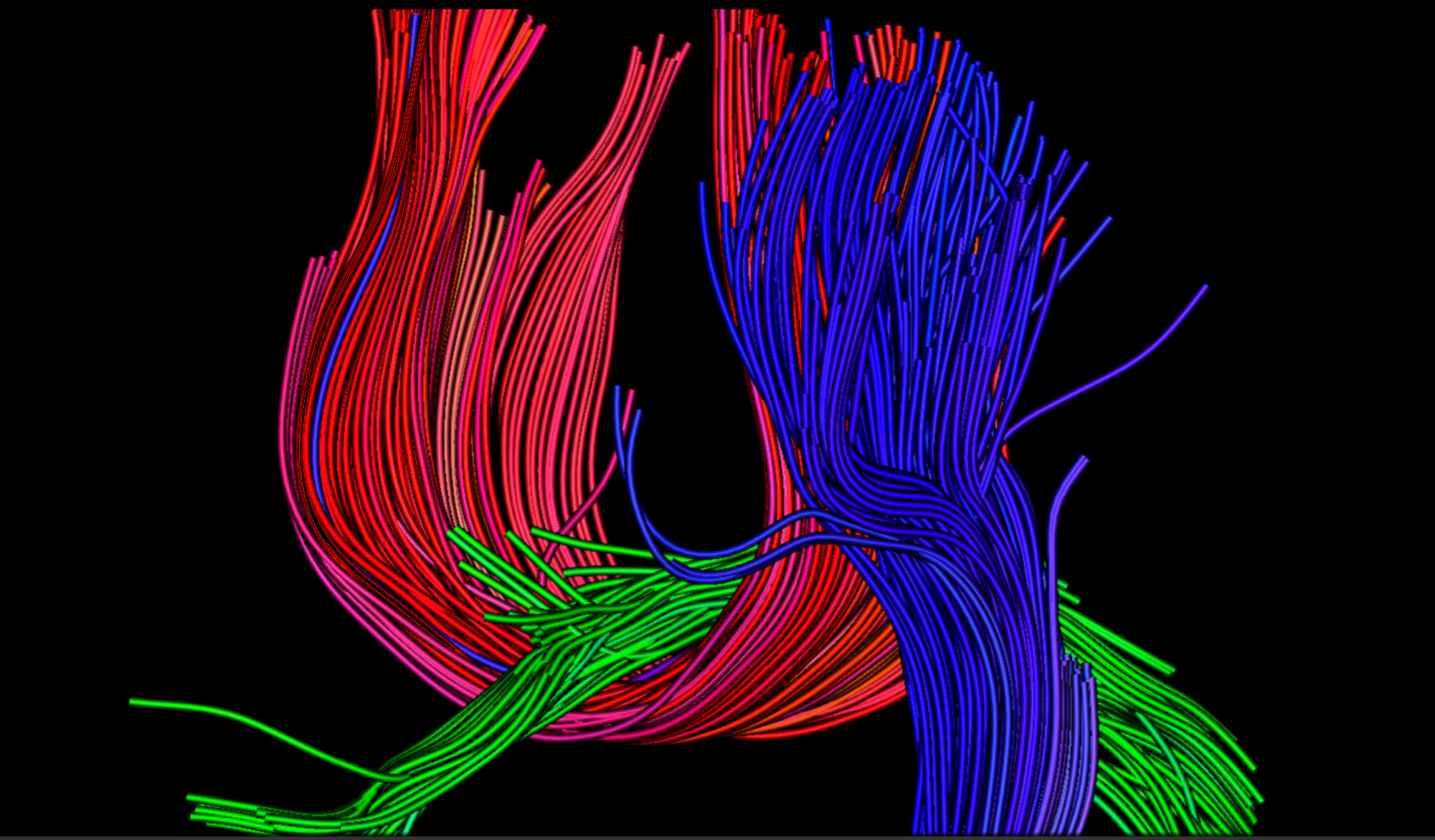
$r_0 = 0.5w$

Parameter:
kleinster
Samplingradius

$r_0 = 1.5w$

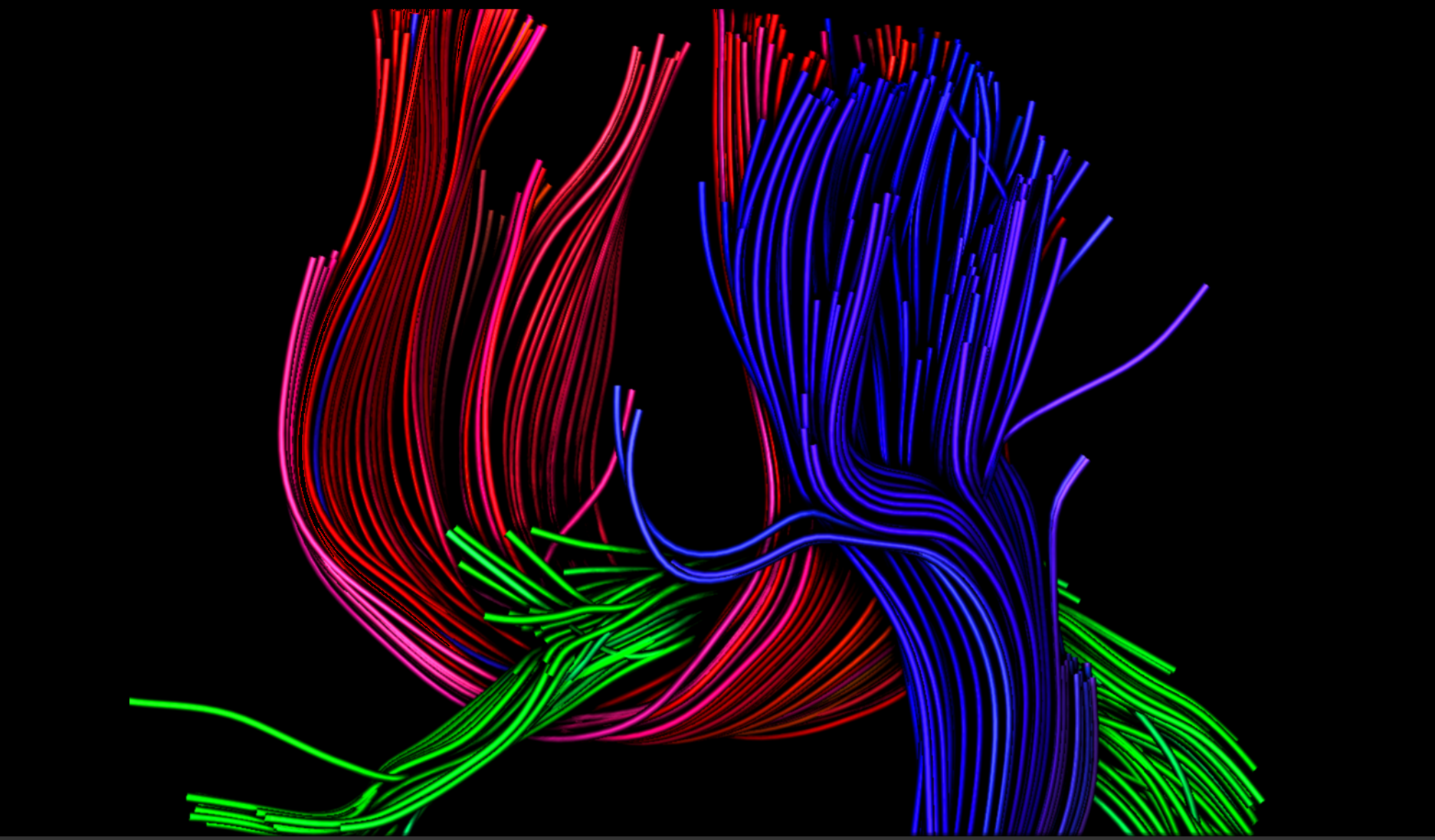
Parameter:
kleinster
Samplingradius

$r_0 = 10w$



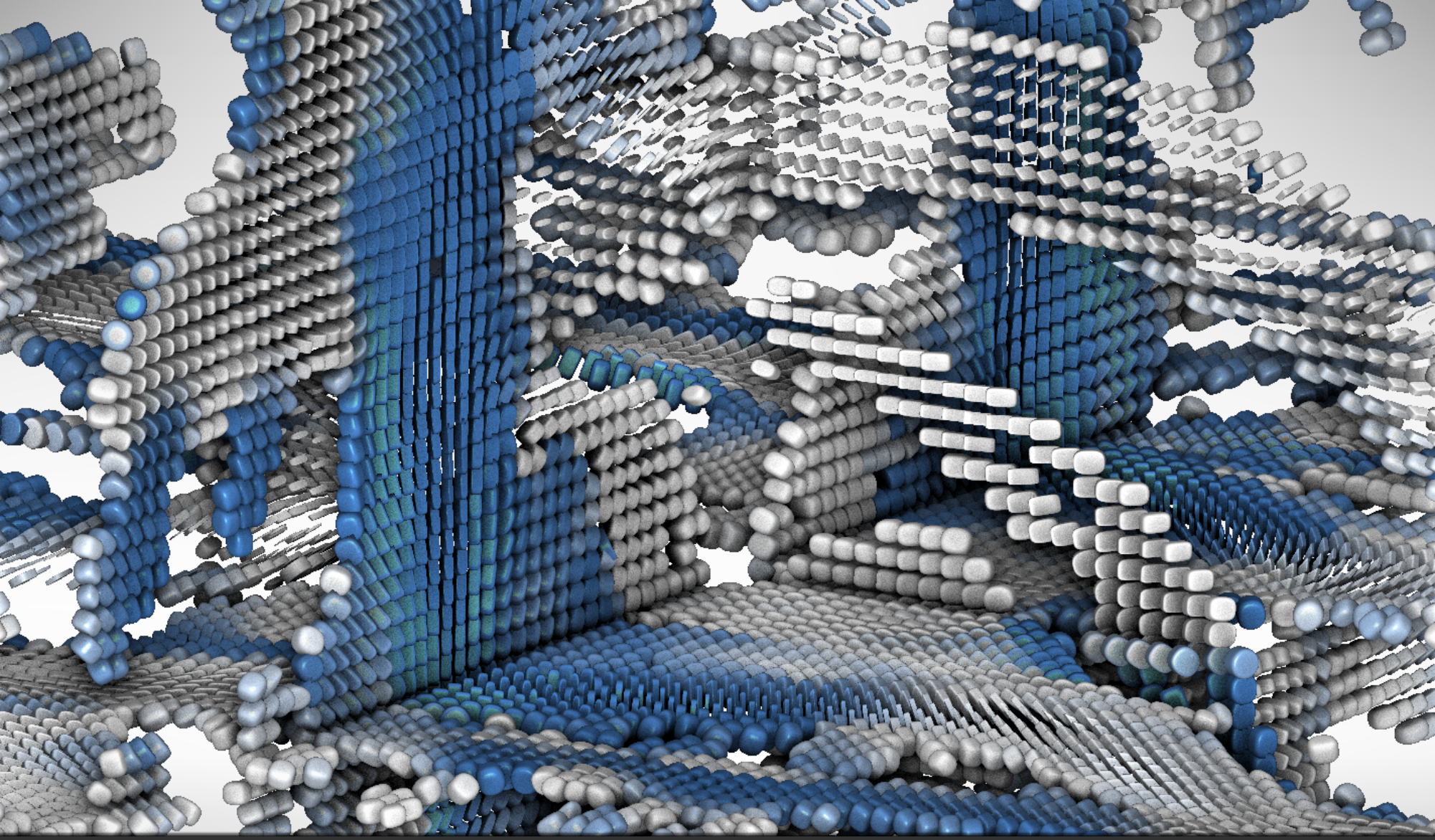
Anwendung: Tubes, ohne LineAO

Auswahl von drei Faserbündeln im Gehirn. Dargestellt durch Röhrchen (Tubes).



Anwendung: Tubes, mit LineAO

Auswahl von drei Faserbündeln im Gehirn. Dargestellt durch Röhrchen (Tubes).

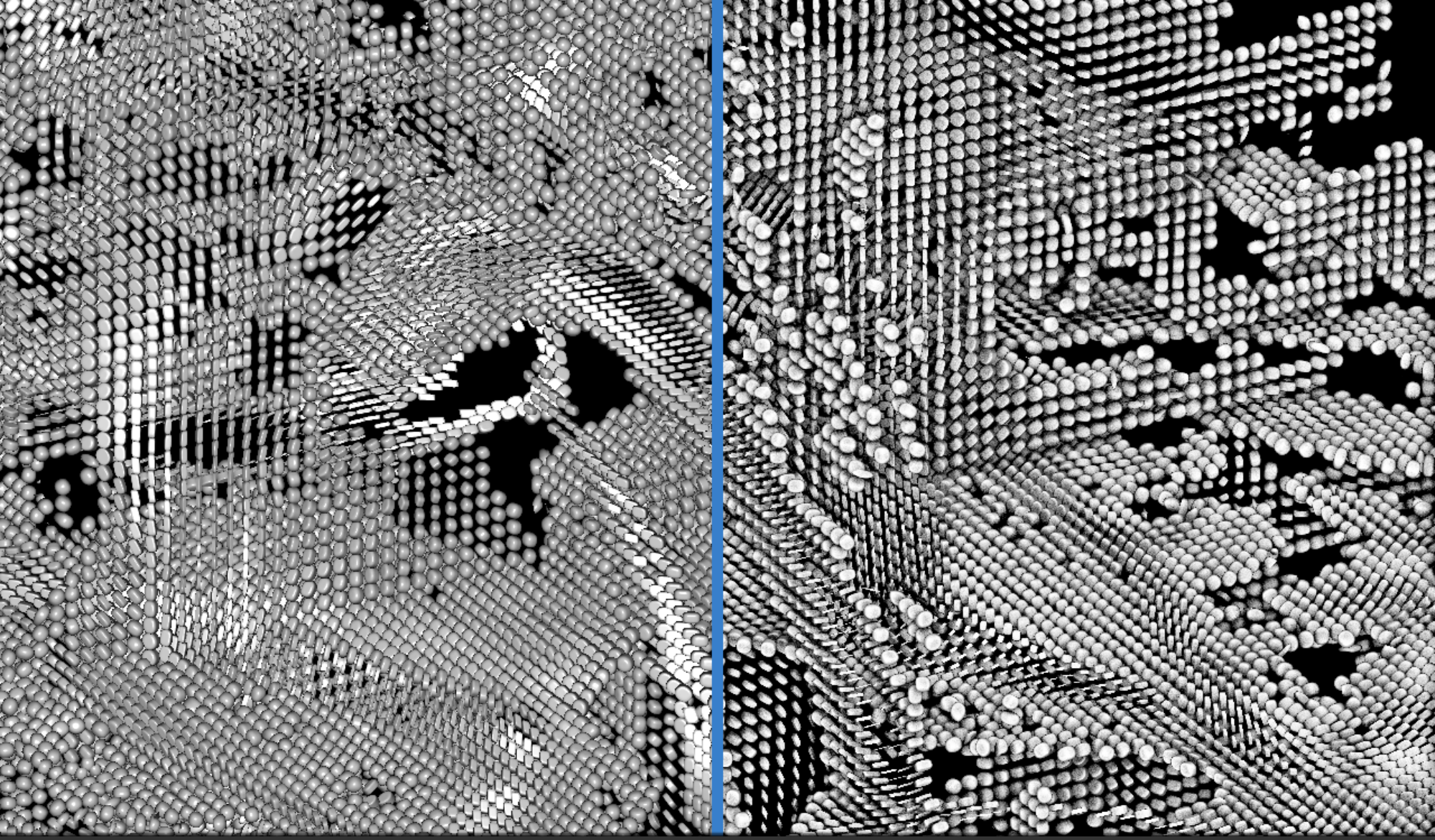


Anwendung: Glyphen, mit PointAO

Publikation: • S. EICHELBAUM, G. SCHEUERMANN, and M. HLAWITSCHKA. PointAO – Improved Ambient Occlusion for Point-based Visualization. EuroVis - Short Papers (2013), 13-17

Anwendung: Glyphen, Phong

Drei Schnitte durch Diffusionsdaten des Gehirns; dargestellt als Superquadric Glyphen.

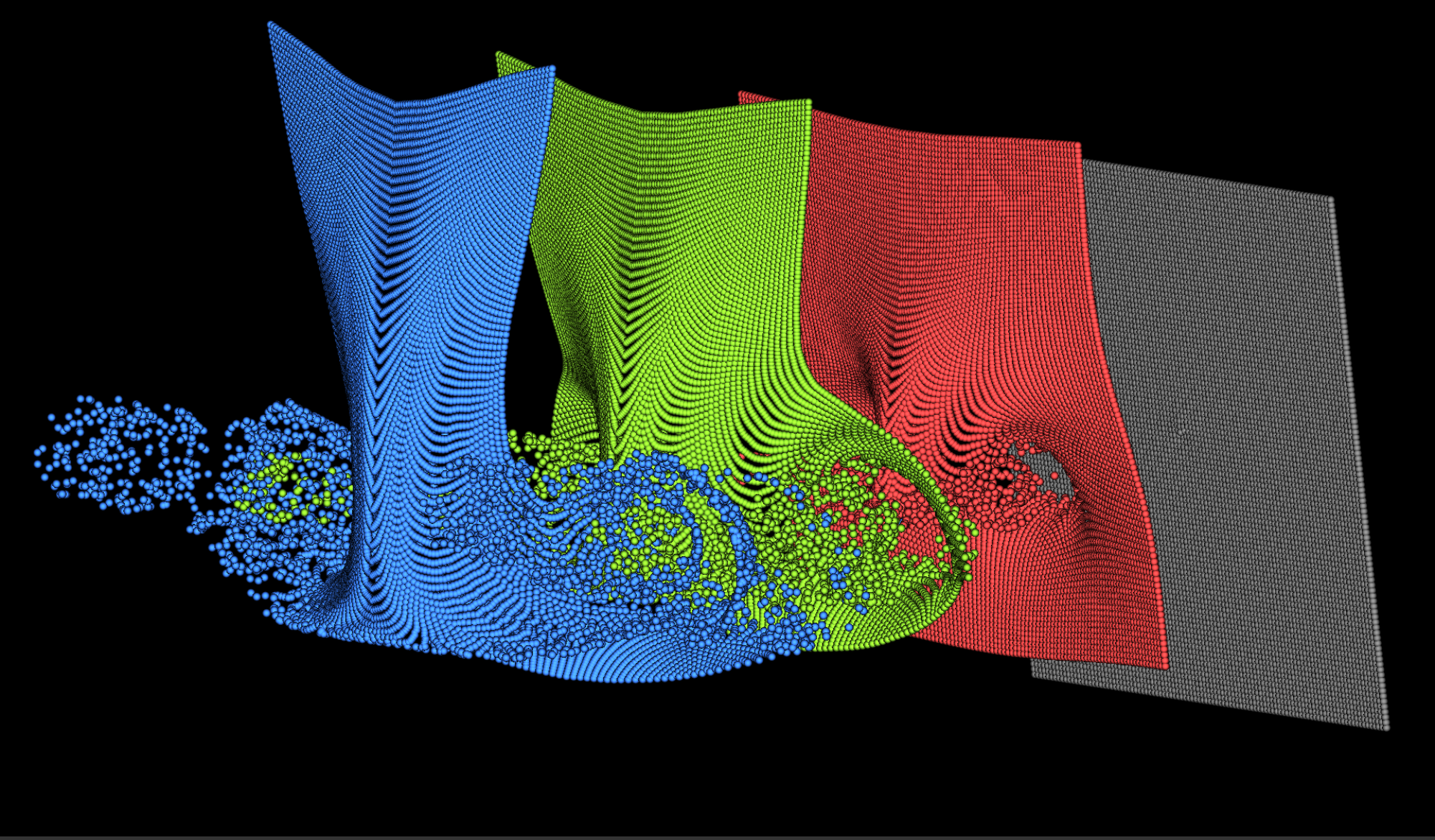


Anwendung: Glyphen, Phong vs. SSAO

Drei Schnitte durch Diffusionsdaten des Gehirns; dargestellt als Superquadric Glyphen.

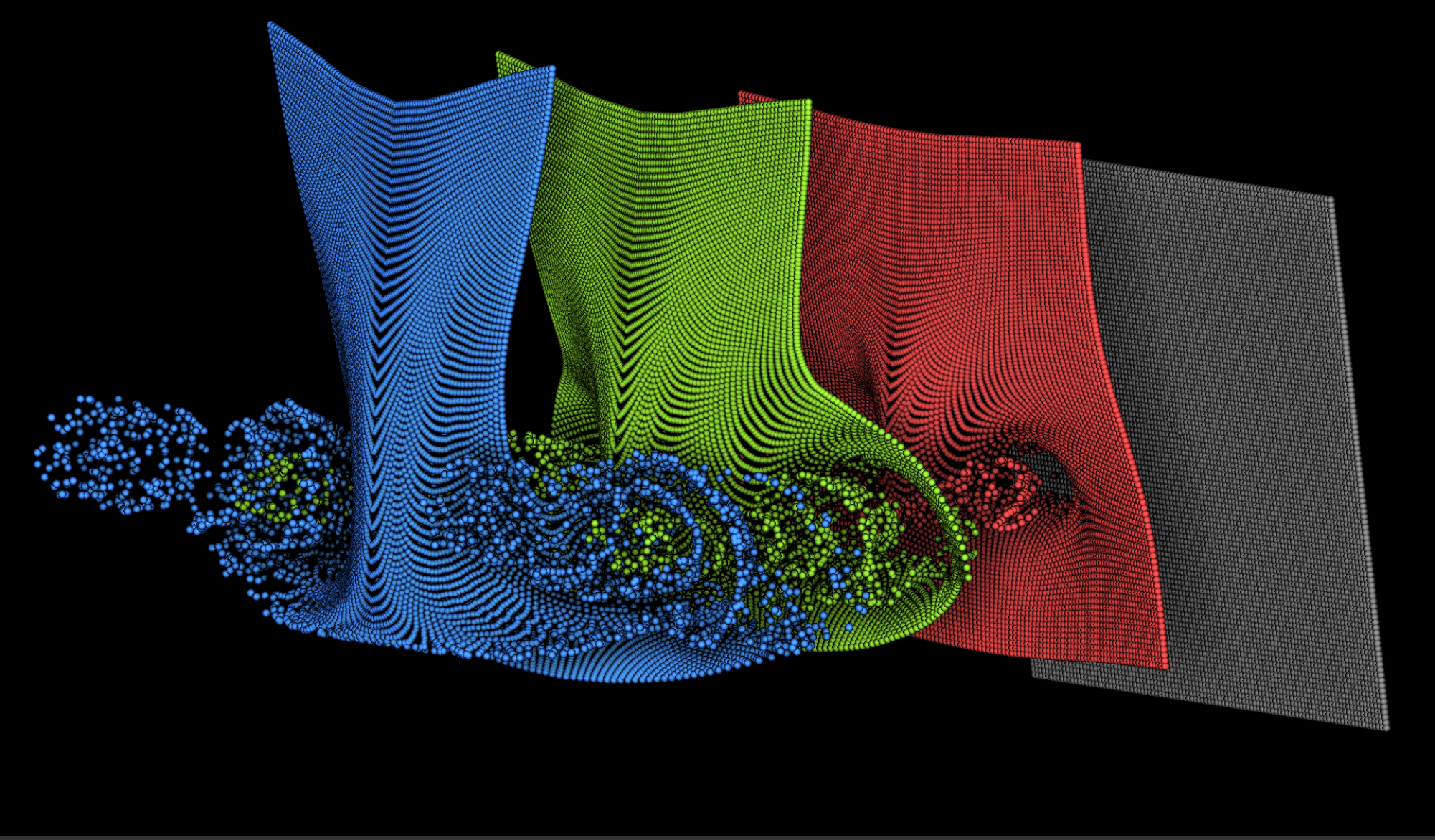
Anwendung: Glyphen, Phong vs. PointAO

Drei Schnitte durch Diffusionsdaten des Gehirns; dargestellt als Superquadric Glyphen.



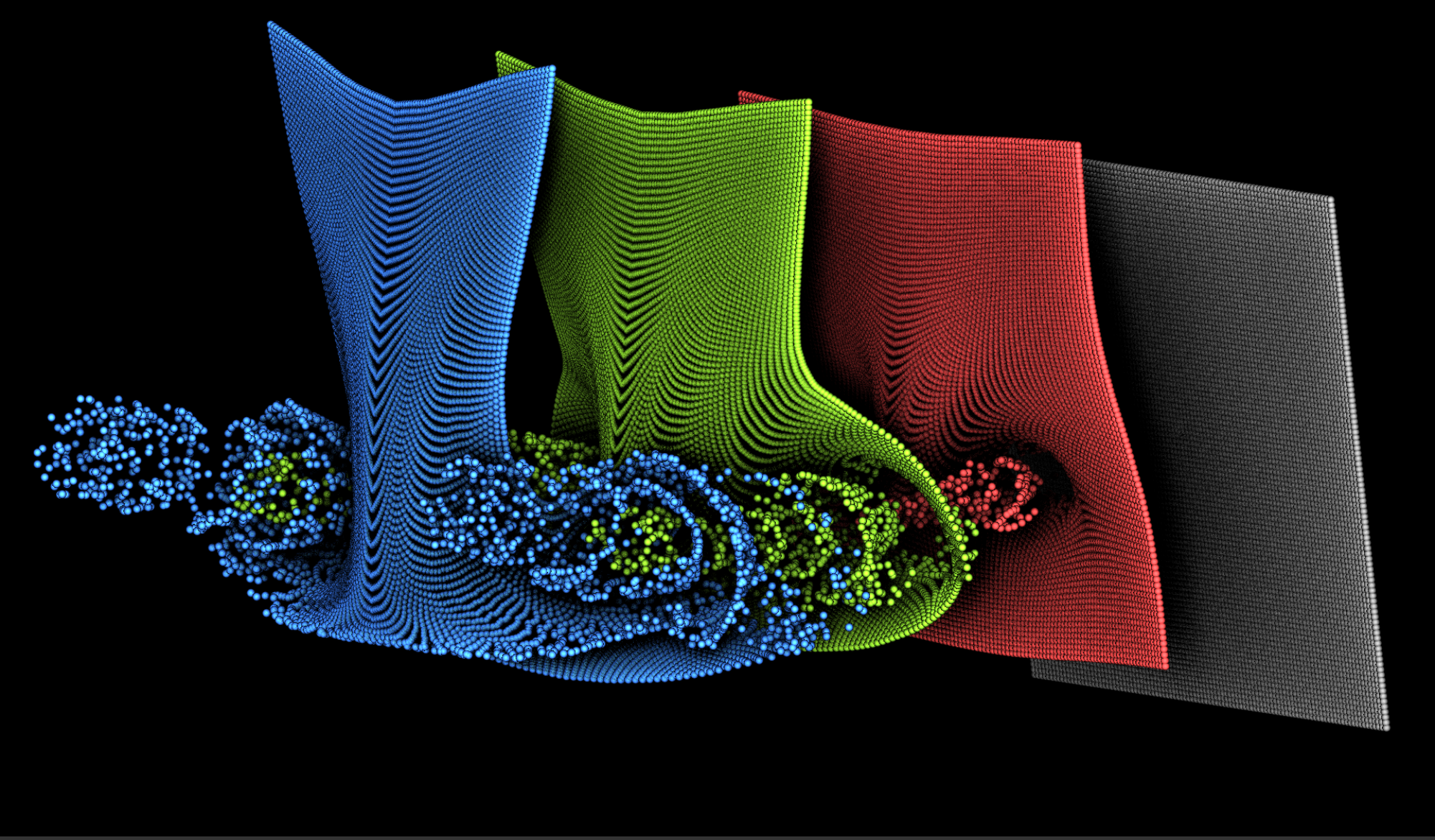
Anwendung: Strömende Partikel, Phong

Strömung von Partikeln in den Luftwirbeln auf einem Nurflügel (Deltawing).



Anwendung: Strömende Partikel, SSAO

Strömung von Partikeln in den Luftwirbeln auf einem Nurflügel (Deltawing).

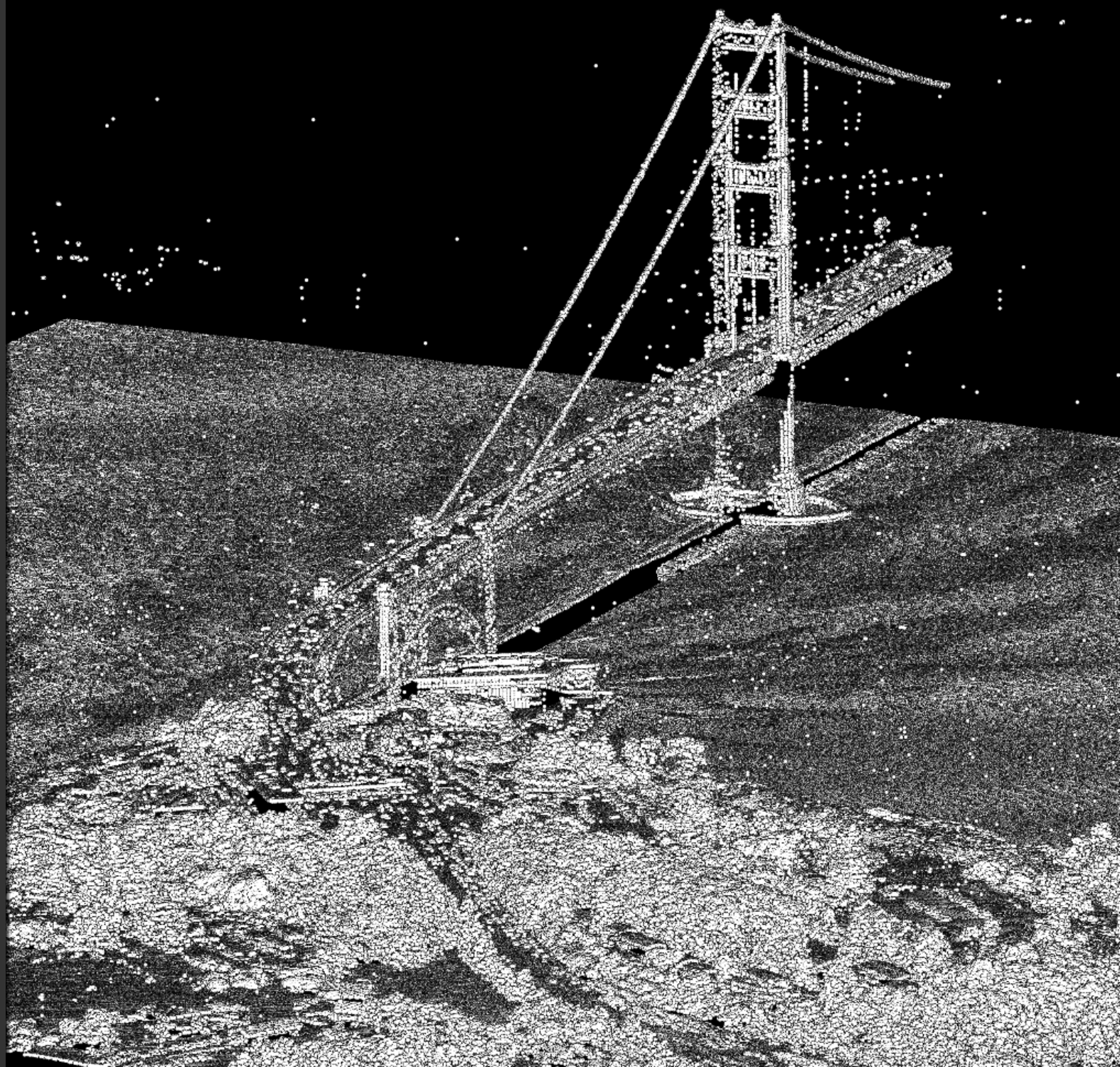


Anwendung: Strömende Partikel, mit PointAO

Strömung von Partikeln in den Luftwirbeln auf einem Nurflügel (Deltawing).

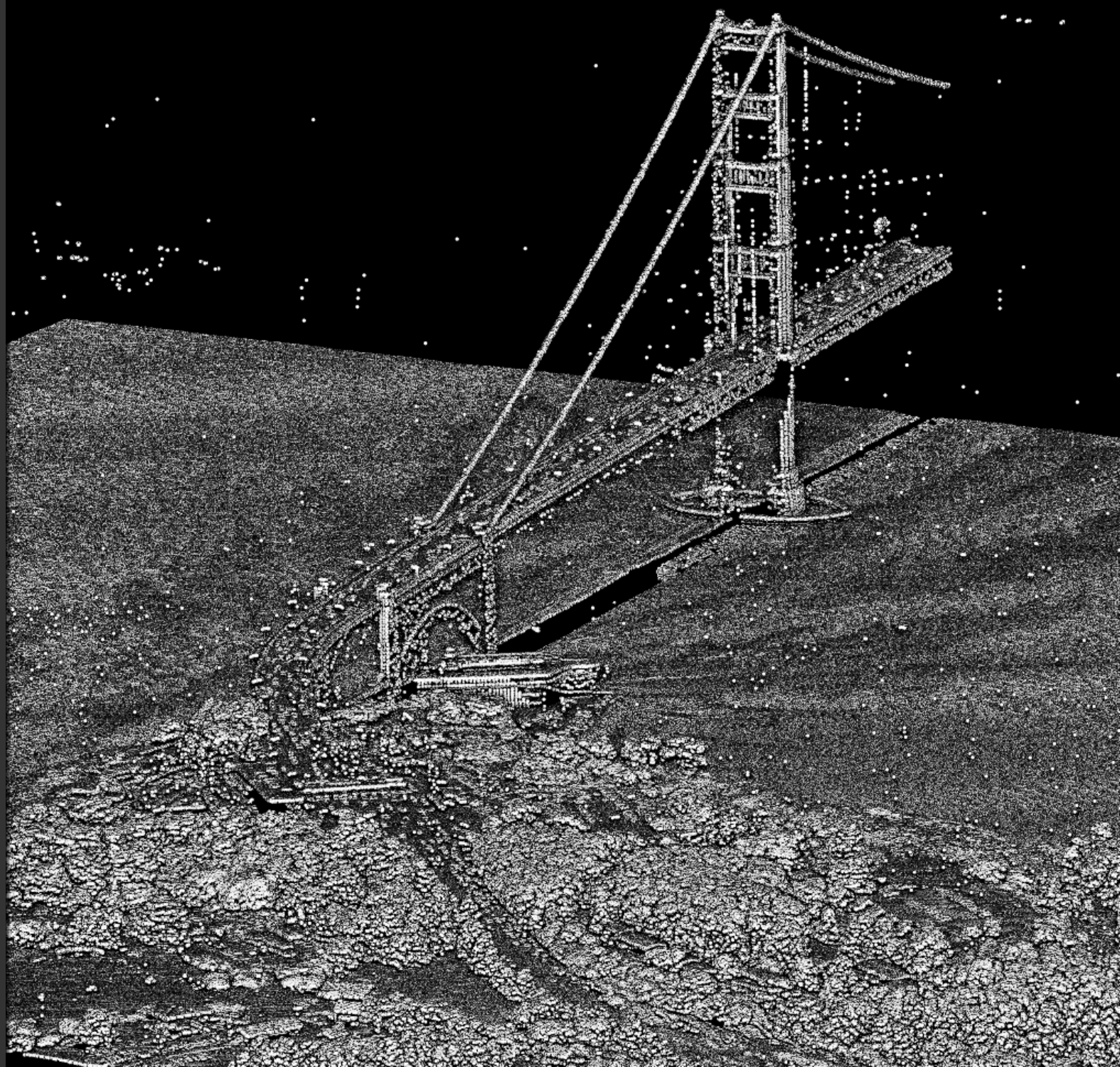
Anwendung: LIDAR, Phong

Laser Scan der Golden Gate Bridge in San Francisco, 14.614.769 Punkte.



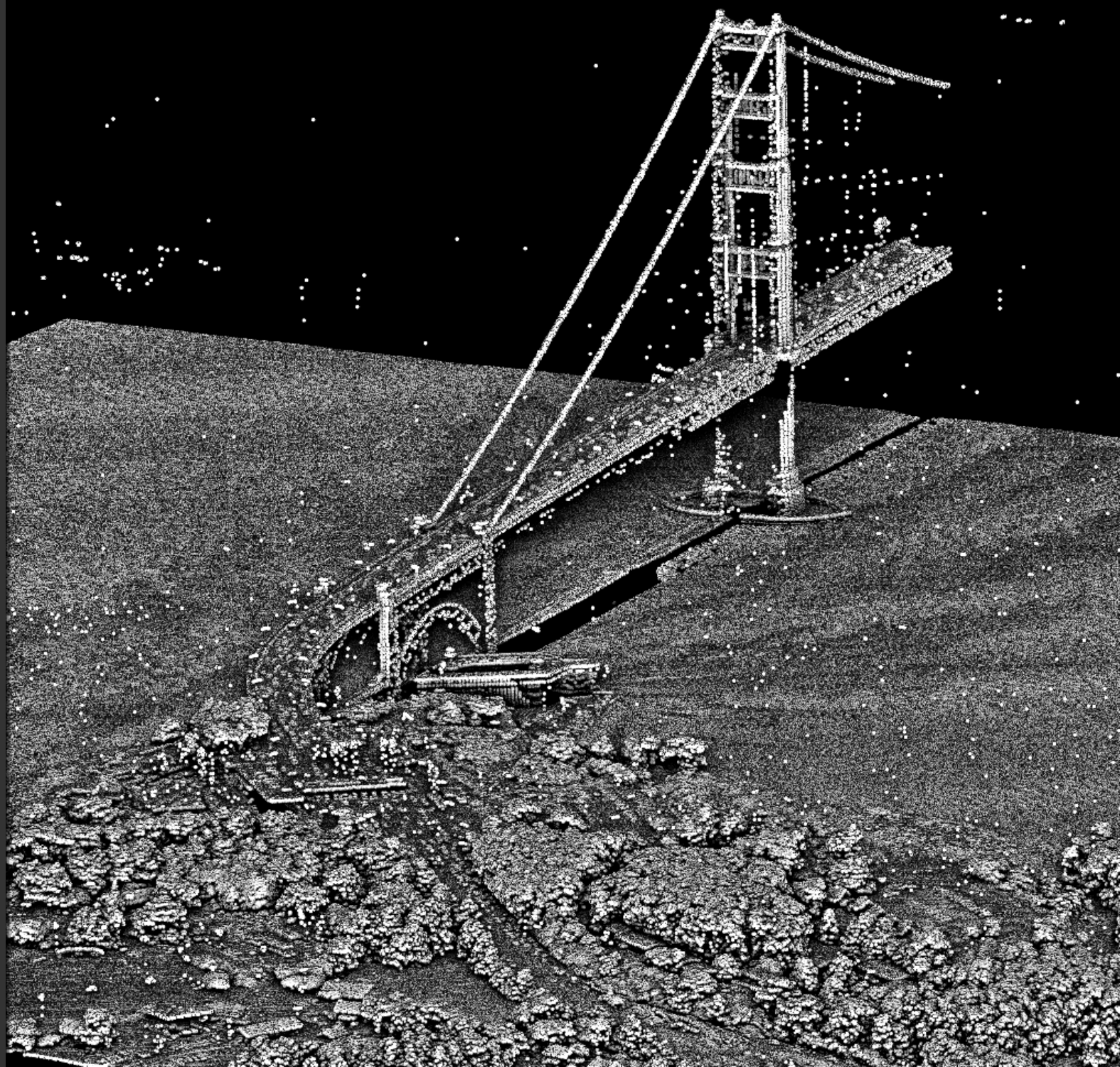
Anwendung: LIDAR, SSAO

Laser Scan der Golden Gate Bridge in San Francisco, 14.614.769 Punkte.



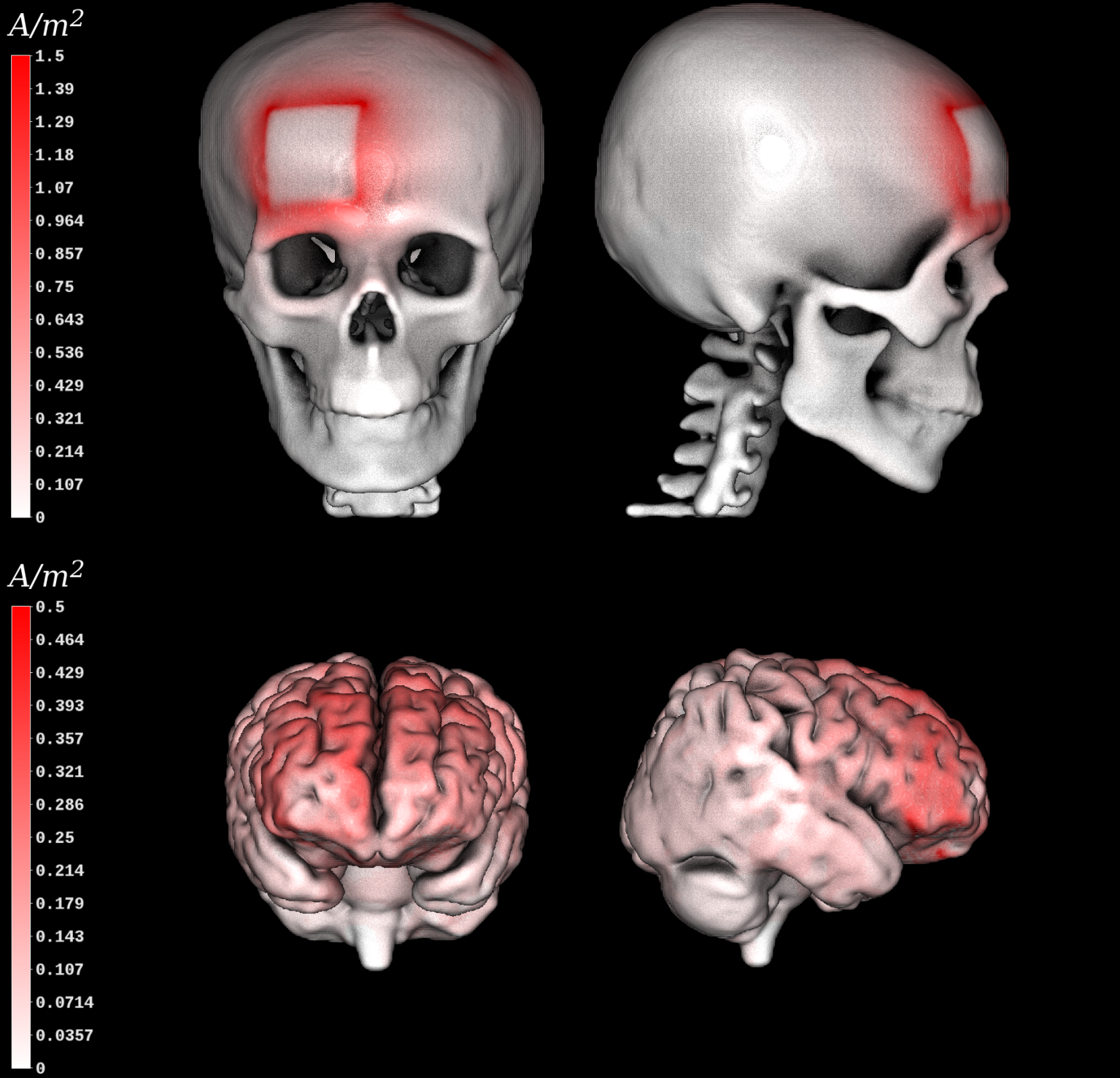
Anwendung: LIDAR, PointAO

Laser Scan der Golden Gate Bridge in San Francisco, 14.614.769 Punkte.



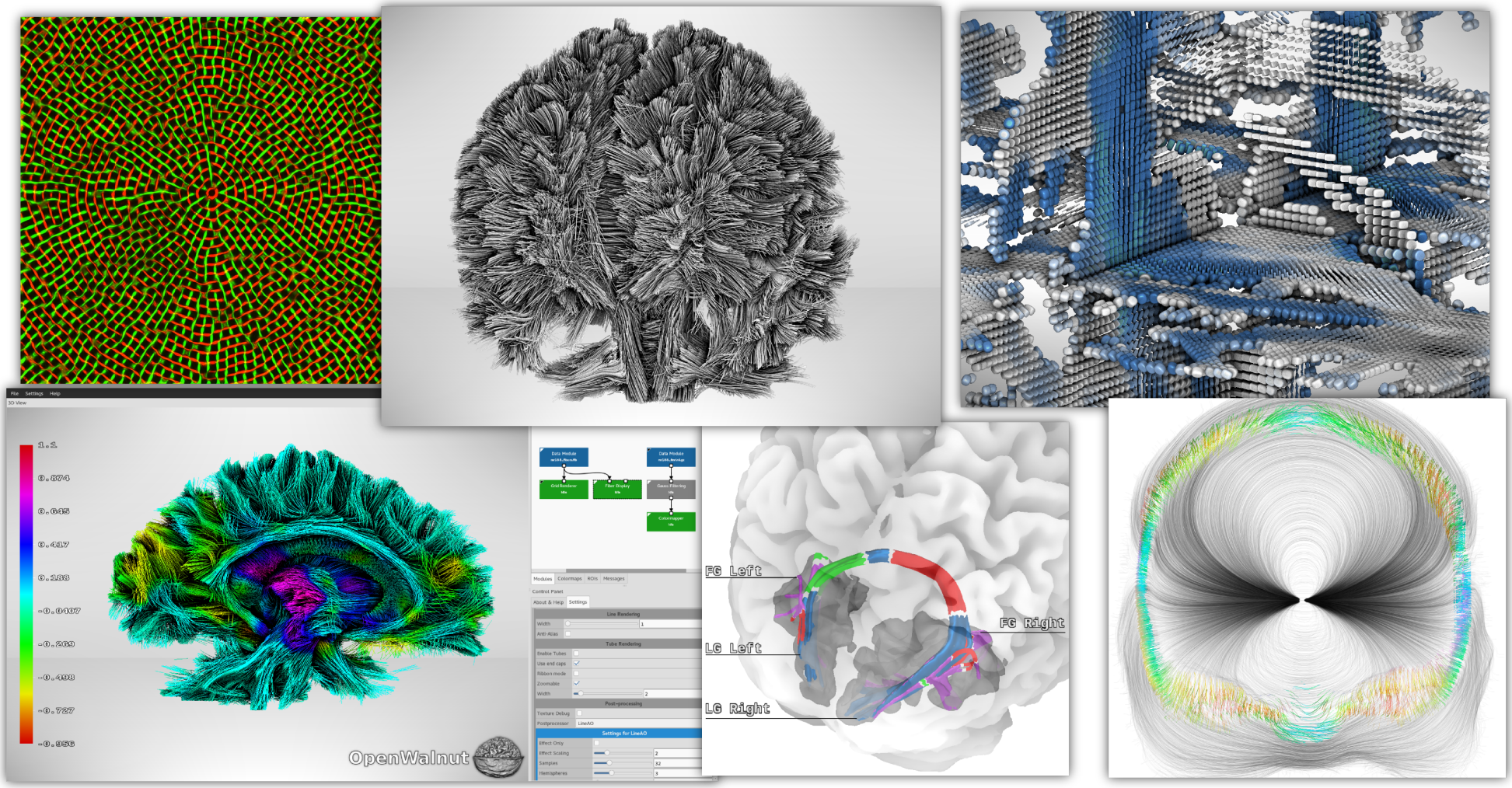
Anwendung: Isoflächen

Grenzflächen des Schädels und Gehirns mit eingetragener Stromdichte.



Teil 2

Computergrafik in der Visualisierung



Zusammenfassung: Visualisierung, Software, Grafik

Publikationen: `sebastian-eichelbaum.de/publications`

Implementationen: `openwalnut.org`

Vielen Dank. Fragen?

OpenWalnut ist

- OpenWalnut ist ...
  - Visualisierungssystem
  - > Warum noch ein Visualisierungssystem?
  - > Worin hebt sich OpenWalnut ab?

OpenWalnut ist

- OpenWalnut ist ...
  - Visualisierungssystem
  - > Warum noch ein Visualisierungssystem?
  - > Worin hebt sich OpenWalnut ab?
- Ziel: das Beste aus zwei Welten
  - > Das programmierbare Werkzeug

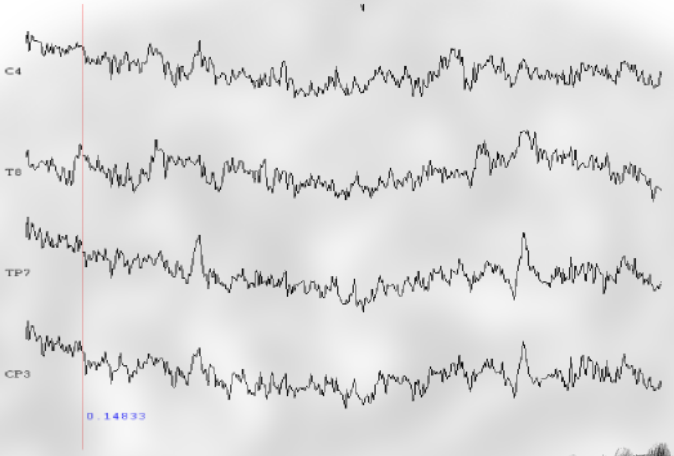
Kriterium: Open Source

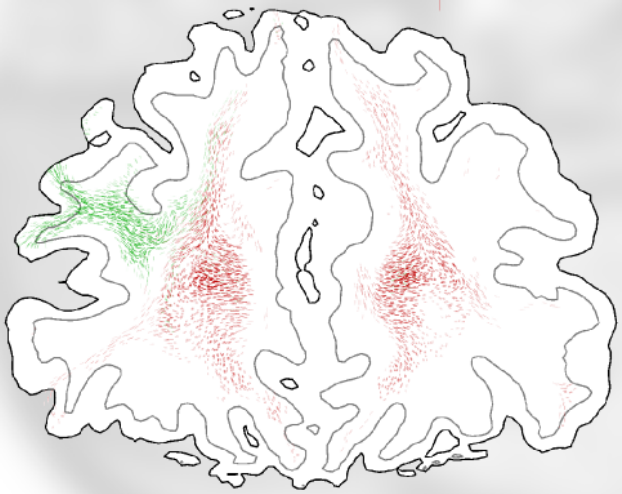
```
    virtual bool connectable( boost::shared_ptr<WModuleConnector> con )
    {
        // since WModuleInputData::connectable already does all the type checking, we simply forward the call
        return WModuleOutputConnector::connectable( con );
    };

    /**
     * Returns the prototype of the Type T used in this connector.
     *
     * \return the prototype of the transfered type.
     */
    virtual boost::shared_ptr< WPrototyped > getTransferPrototype()
    {
        // get prototype or the data pointer currently set
        return ( m_data == boost::shared_ptr< T >() ) ? T::getPrototype() : boost::static_pointer_cast< WPrototyped >( m_data );
    };

protected:
private:
    /**
     * The data associated with this connector.
     */
    boost::shared_ptr< T > m_data;
};

template < typename T >
typename WModuleOutputData< T >::PtrType WModuleOutputData< T >::create( boost::shared_ptr< WModule > module, std::string name,
                                                                                                          std::string description )
{
    typedef typename WModuleOutputData< T >::PtrType PTR;
    typedef typename WModuleOutputData< T >::Type TYPE;
    return PTR( new TYPE( module, name, description ) );
}

template < typename T >
typename WModuleOutputData< T >::PtrType WModuleOutputData< T >::createAndAdd( boost::shared_ptr< WModule > module, std::string name,
                                                                                                                std::string description )
{
    typename WModuleOutputData< T >::PtrType c = create( module, name, description );
    module->addConnector( c );
    return c;
}

#endif  // WMODULEOUTPUTDATA_H
```

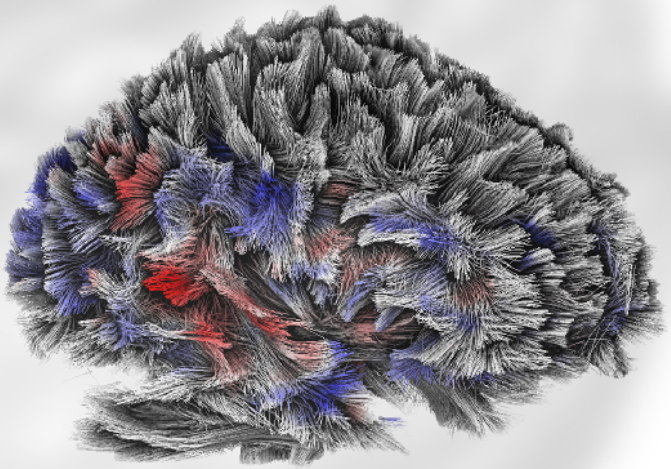
Vorteil: Nachvollziehbarkeit, Anpassbarkeit

Filter: ~~Amira~~, ~~MeVisLab~~

Kriterium: Universell







Vorteil: Erlaubt das Lösen von neuen Problemen

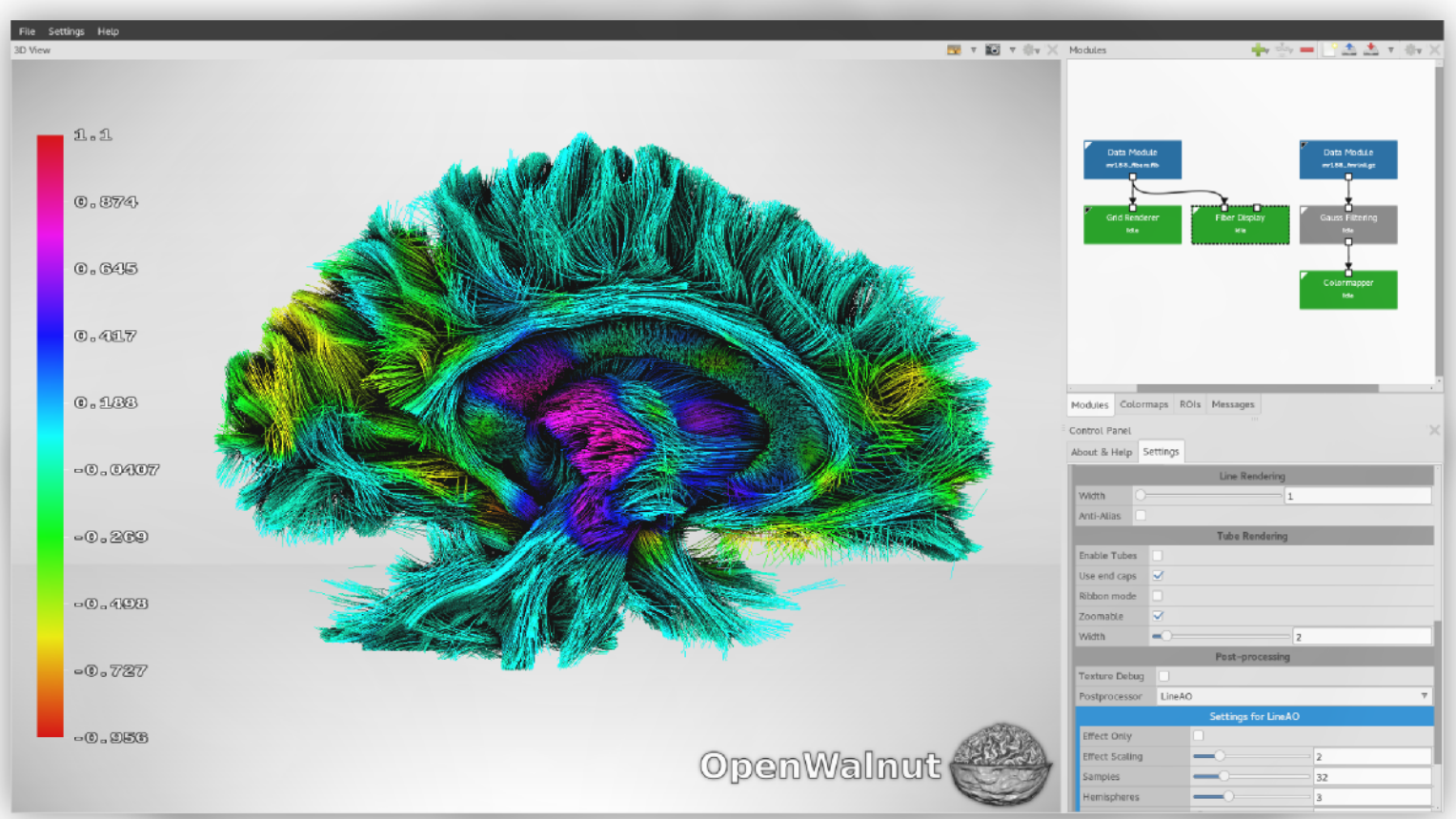
Filter: ~~MedINRIA~~

Kriterium: Erweiterbar

Vorteil: Erlaubt neue Herangehensweisen

Filter: ~~Mayavi~~

Kriterium: Grafische Benutzerschnittstelle



Vorteil: Macht das Framework benutzbar

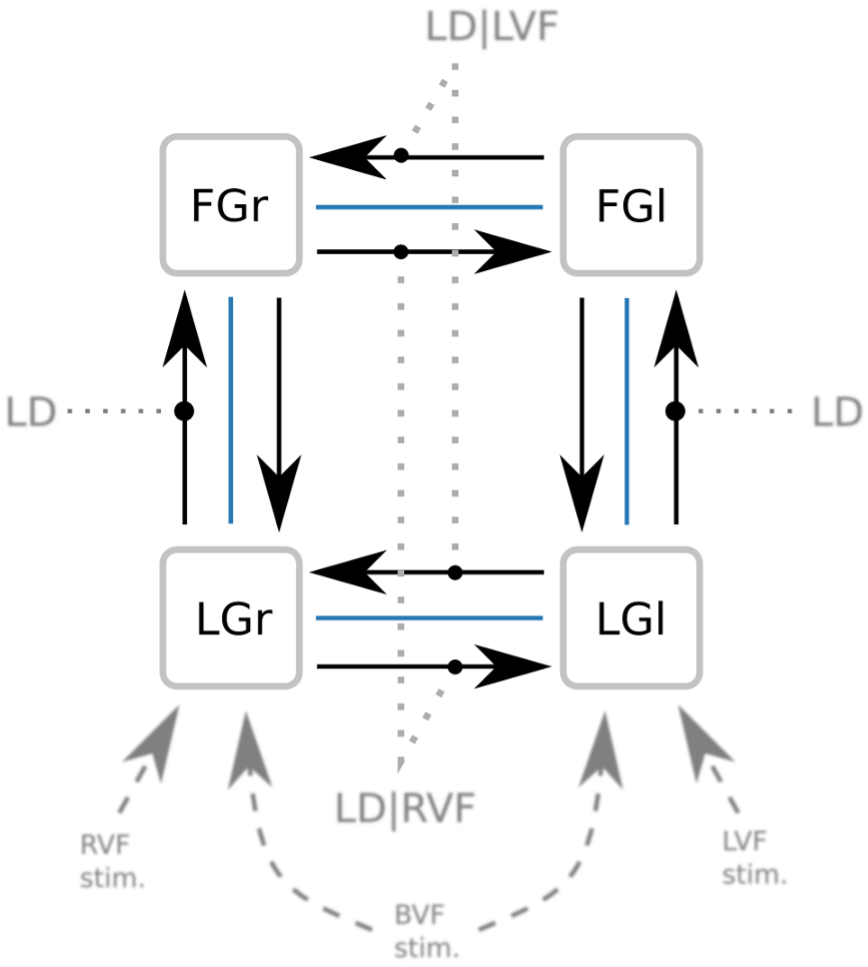
Filter: ~~ParaView~~, ~~SCIRun~~

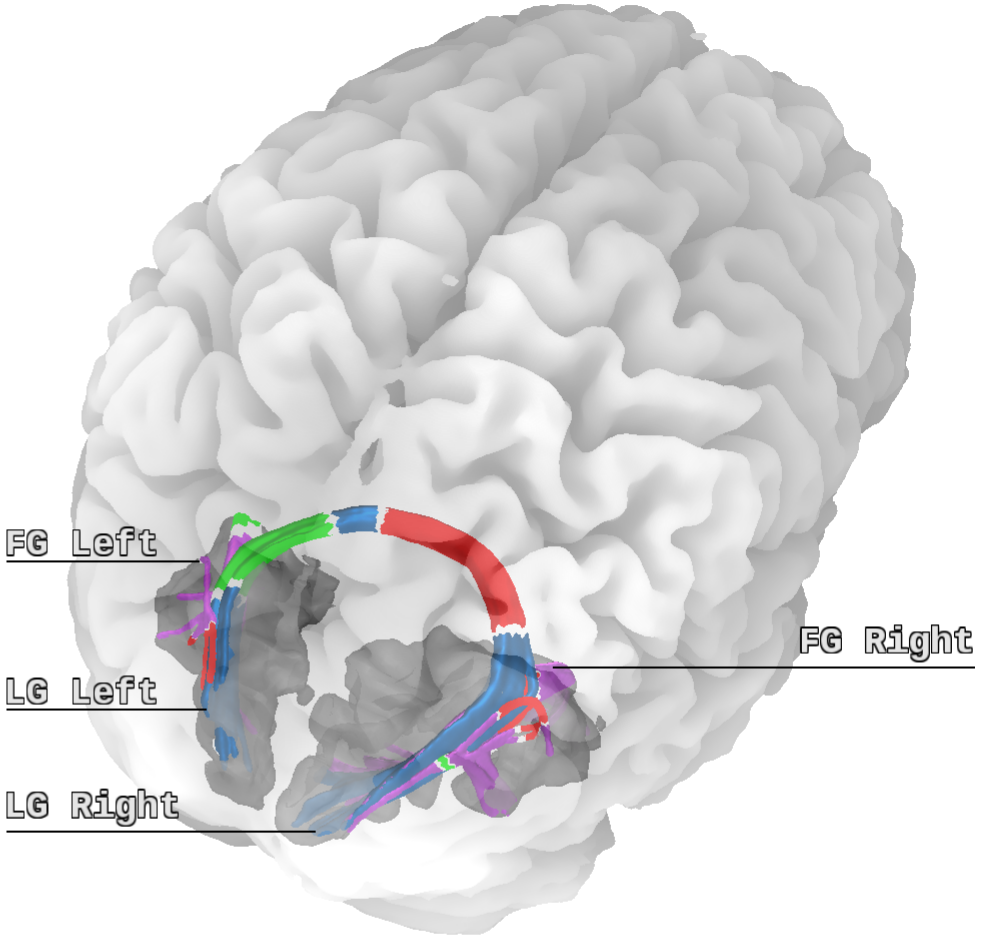
Kriterium: Verfügbarkeit

Vorteil: Erlaubt die Verwendung und direkten Einstieg

Wissenschaftliche Publikationen

- S. EICHELBAUM, M. GOLDAU, S. PHILIPS, A. REICHENBACH, R. SCHURADE, and A. WIEBEL. **Open- Walnut: A New Tool for Multi-modal Visualization of the Human Brain.** *EG VCBM 2010 Posters. 2010*
  Online: http://sebastian-eichelbaum.de/pub10d
- S. EICHELBAUM, M. HLAWITSCHKA, A. WIEBEL, and G. SCHEUERMANN. **OpenWalnut - An Open- Source Visualization System.** *Proceedings of the 6th High- End Visualization Workshop. Ed. by W. Benger, A. Gerndt, S. Su, W. Schoor, M. Koppitz, W. Kapferer, et al. 2010, 67–78*
  Online: http://sebastian-eichelbaum.de/pub10e
- S. EICHELBAUM, M. HLAWITSCHKA, and G. SCHEUERMANN. **OpenWalnut: An Open-Source Tool for Visualization of Medical and Bio-Signal Data.** *Biomedical Engineering / Biomedizinische Technik. Ed. by O. Dössel. 2013*
  Online: http://sebastian-eichelbaum.de/pub13c





Effektive Konnektivität: abstraktes Graphmodell im anatomischen Zusammenhang

- S. EICHELBAUM, A. WIEBEL, M. HLAWITSCHKA, A. ANWANDER, T. KNÖSCHE, and G. SCHEUERMANN.
Visualization of Effective Connectivity of the Brain.
Proceedings of the 15th International Workshop on Vision, Modeling and Visualization (VMV). 2010, 155–162

Seminarraum P-701