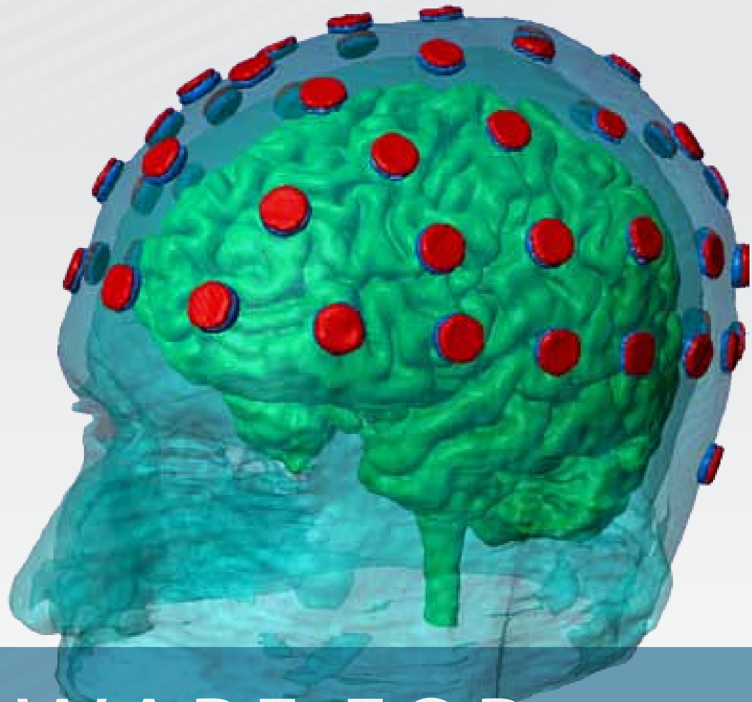

SIMPLEWARE FOR BIO ELECTROMAGNETICS

simpleware
3D image visualisation, analysis and model generation

Case Study

Finite Element Meshes for Transcranial Direct Current Stimulation (tDCS)

Transcranial direct current stimulation (tDCS) represents a non-invasive neuromodulatory technique that delivers a weak direct current to the brain, and can be used to treat brain injuries, strokes, and other neurological conditions. tDCS can be optimised and individualised through anatomic and patient-specific computational models that can simulate electric field distribution and current flow.

Finite Element models were developed using a Simpleware research license as part of a long-term study into calculating and optimising tDCS for different patient-specific treatments. High-resolution MRI data was used to generate human head models with segmented tissues featuring specific electrical properties. Image data was then exported as volume meshes to solvers to investigate optimal electric field distributions under different conditions.

Characteristics

» Based on MRI and fMRI data
» Image processing of tissue using Simpleware ScanIP and in-house tools
» Integration of CAD models with image data
» Generation of high quality volume meshes
» Simulation of electric field distribution in commercial solvers
» Complete workflow carried out on a standard workstation

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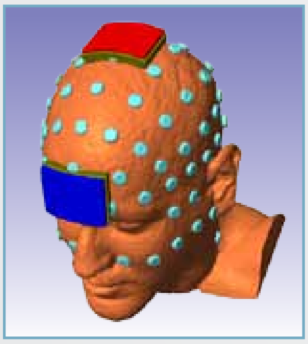
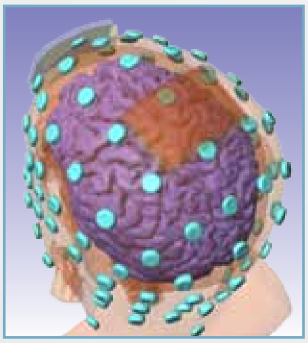
SEGMENTATION AND CAD INTEGRATION IN SCANIP +CAD

A 3-T scanner equipped with a Synergy-L Sensitivity Encoding (SENSE) head coil was used to obtain a high-resolution T1-weighted magnetisation prepared rapid gradient echo (MPRAGE) MRI scan from a healthy subject. The researchers used in-house segmentation algorithms and tissue probability maps to separate skin, fat, skull, cerebral spinal fluid (CSF), grey and white matter. Image data was then imported into ScanIP to improve segmentation and demarcate tissue compartment boundaries. Simpleware module +CAD was also used to integrate anode, cathode and sponge models into segmented image data according to the international EEG 10-20 system.

MESHING IN SIMPLEWARE +FE

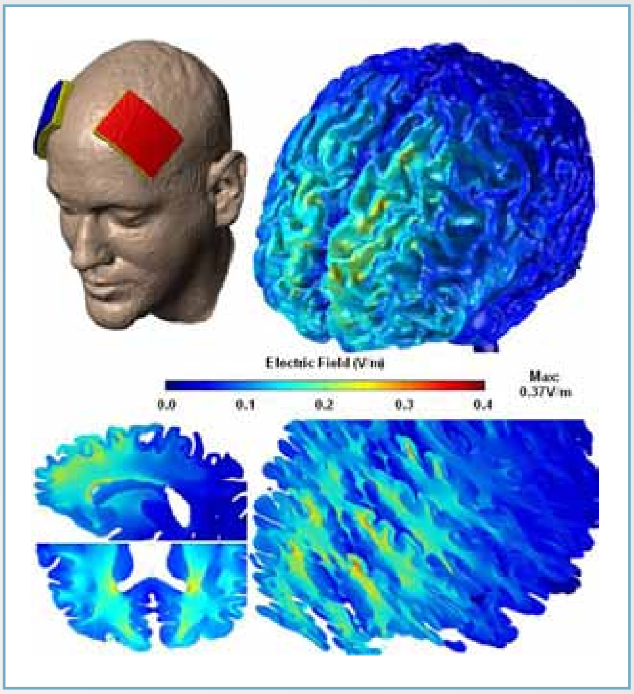
Simpleware +FE was used to convert segmented image data into a three-dimensional volume mesh comprising of seven segmented tissue masks and the imported electrode montage. An adaptive +FE Free mesh algorithm was employed to reduce the number of elements and the degrees of freedom for the image without compromises in computational accuracy. A compact mesh with a compound coarseness of -17 was created, and featured 9.5×10^6 tetrahedral elements with 13.0×10^6 degrees of freedom. The exported mesh was high quality enough to remove the need for further smoothing prior to export.





SIMULATION IN COMSOL

The head model was directly imported into COMSOL Multiphysics© and electrostatic volume conductor physics were applied. Exterior boundaries were defined as electrically insulated, and interior boundaries as continuous across interfaces. Anode and cathode placements were also altered to meet simulation parameters, and material properties were assigned to each mask. A linear solver with conjugate gradients and algebraic multigrid preconditions was applied to solve the Laplace-Equation for simulating current distribution. Induced EF and current density distribution was also plotted for the simulation.



CONCLUSION

This case study indicates how computational models created using Simpleware software enable pre-treatment analysis of electric field distribution and cortical current flow patterns for a range of electrode montages and stimulation doses involving tDCS. Models have been used to guide tDCS design and optimisation, with applications to areas such as the treatment of strokes, skull defects, and other neural conditions that can significantly benefit from tailored therapy protocols.