# Comets v. 1.0
## Matlab® toolbox

# User Manual
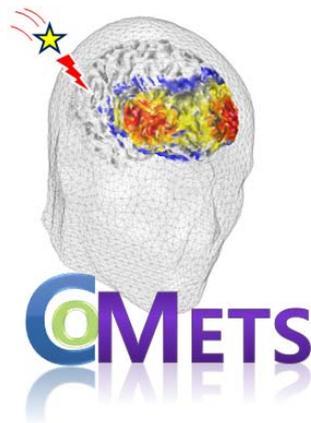


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# Comets

A Matlab toolbox for simulating electric field due to tDCS
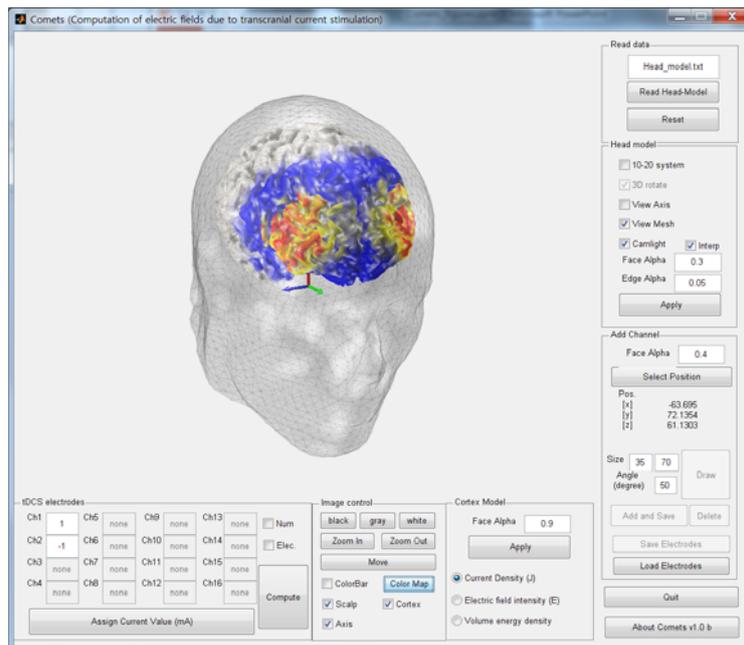


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# Introduction

**Comets** (**com**putation of **e**lectric fields due to **t**ranscranial current **s**timulation) is a free Matlab toolbox for analyzing electric fields on human cerebral cortex generated by transcranial directed current stimulation (tDCS). tDCS is a novel noninvasive brain electrical stimulation technique that can modulate cortical excitability of human brain by transmitting a small direct current (DC) through electrode pads attached on the scalp. The tDCS technique has been studied in a variety of clinical and research fields, especially as a potential treatment tool for neuropsychiatric diseases and neurological disorders including depression, epilepsy, electroanalgesia, stroke, Alzheimer's disease, chronic pain, tinnitus, and Parkinson's disease.

Since no imaging modality is currently able to image electric field distributions generated by tDCS during in-vivo human experiments, computer simulation of electric fields is becoming more and more important in recent tDCS studies. electric field distributions are estimated from numerical field simulations using realistic head models derived from structural magnetic resonance (MR) imaging (Miranda et al 2006, Wagner et al 2007b, Datta et al 2009, 2010, Im et al 2008, Park et al 2011). Indeed, 3D field simulations based on the 3D finite element method (FEM) widened our insights into the underlying mechanisms of stimulating current conduction (Dmochowski et al 2011, Miranda et al 2006, 2007, Wagner et al 2007b, Datta et al 2010, Holdefer et al 2006), accelerated the development of new electrode montages (Datta et al 2009, Dmochowski et al 2011, Im et al 2008, 2012, Park et al 2011), and enabled more accurate field concentrations to targeted brain areas (Dmochowski et al 2011, Halko et al 2011, Mendonca et al 2011).

Despite of the importance of computer simulation of electric field due to tDCS, the 3D computer simulation study could not be performed by general researchers,

especially researchers in the medical fields, as there was no software designed to simulate electric field due to tDCS. The Computational NeuroEngineering (CoNE) laboratory of Hanyang University now releases a new Matlab toolbox, named **Comets**, which can provide 3D images of electric field distributions for any combinations of stimulating electrode pairs. Comets supports graphical user interface (GUI) environment in which any inexperienced users can readily control, analyze, and visualize various functions related to the 3D electric field simulation.
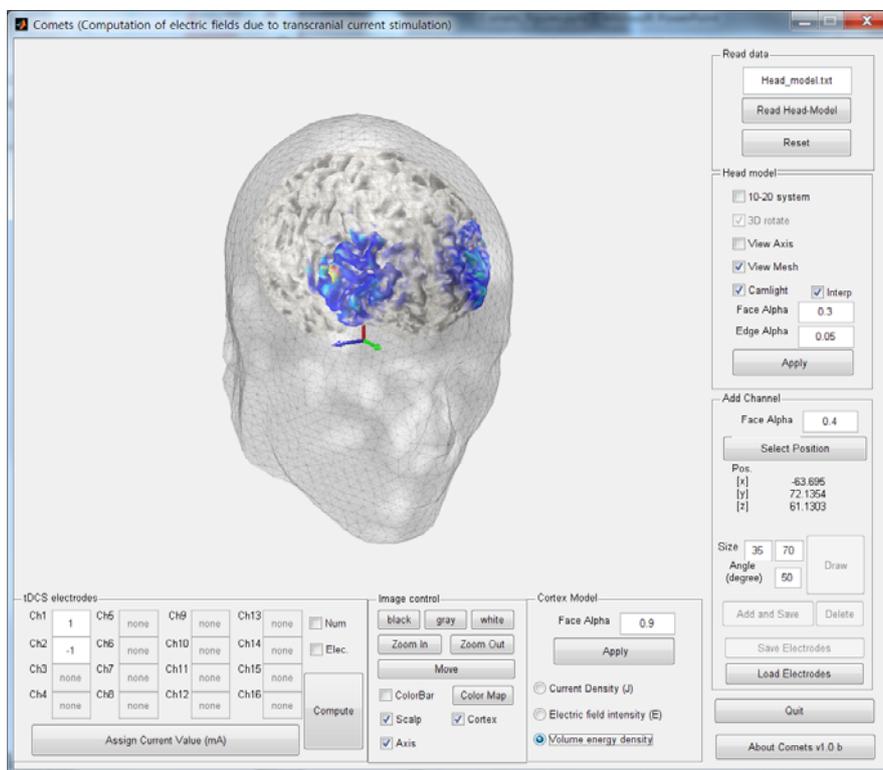


**Figure 1 3D Images generated from Comets**

Comets requires a MATLAB environment but does not need any supplementary MATLAB toolboxes such as signal processing toolbox, spline toolbox, statistical toolbox, and so on. Graphical user interfaces (GUIs) of the Comets allow users to analyze electric field distributions on the cortical surface intuitively without a need

for MATLAB scripting. Users can not only select various locations for cathode and anode electrodes, but also can adjust the size and orientation of each electrode.

The Comets toolbox can be freely downloaded from the title page of Computational Neuroengineering Laboratory in Hanyang University (http://cone.hanyang.ac.kr) or directly from http://www.cometstool.com for non-commercial and academic uses. Our toolbox cannot be used for a medical use, but for research and education purposes only. A manual describing the details of how to use the toolbox is included as well on the download page. An email account cometstool@gmail.com welcomes user feedbacks for improving the toolbox. We hope that our toolbox can contribute to the popularization of numerical analysis of cortical stimulation current in the field of noninvasive electrical brain stimulation.

Please cite **an article submitted to an international journal** (after the publication) if you use the Comets toolbox for your publications.

# Getting Started

**Comets** requires a **MATLAB environment** but does **not need any MATLAB toolboxes** such as 'Signal Processing Toolbox', 'Spline Toolbox', 'Statistical Toolbox', etc. **Our toolbox cannot be used for a medical use, but for research and education purposes only.**
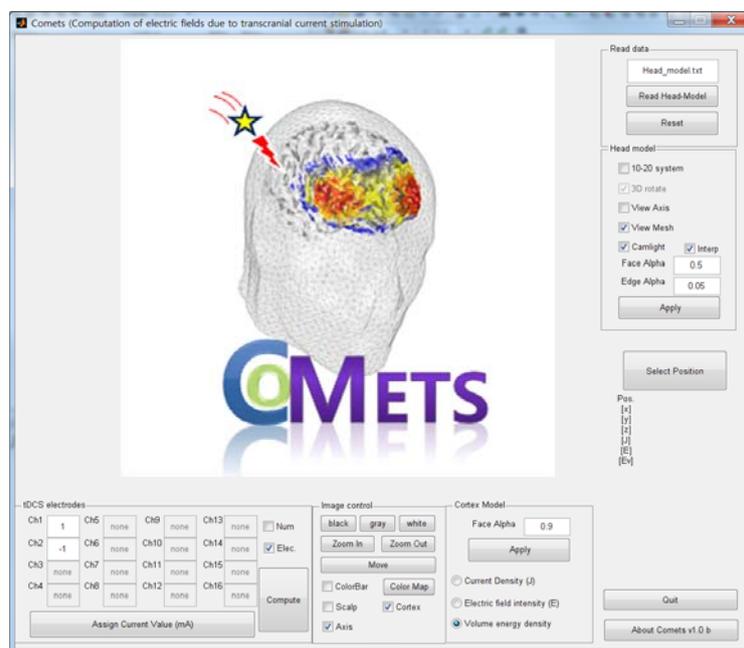


**Figure 2 Main Window**

# 1. Download and Install

➢ The Comets toolbox can be downloaded at http://www.cometstool.com or http://cone.hanyang.com.

➢ Unzip the "Comets.zip" file and put the toolbox in '\Comets' folder or in any folder you like to use.

➢ Start the Comets toolbox by typing, '>> Comets', in the command window of the Matlab after changing the folder path. When you press the 'Enter' key, the Comets toolbox will be started (Figure 3 will appear).
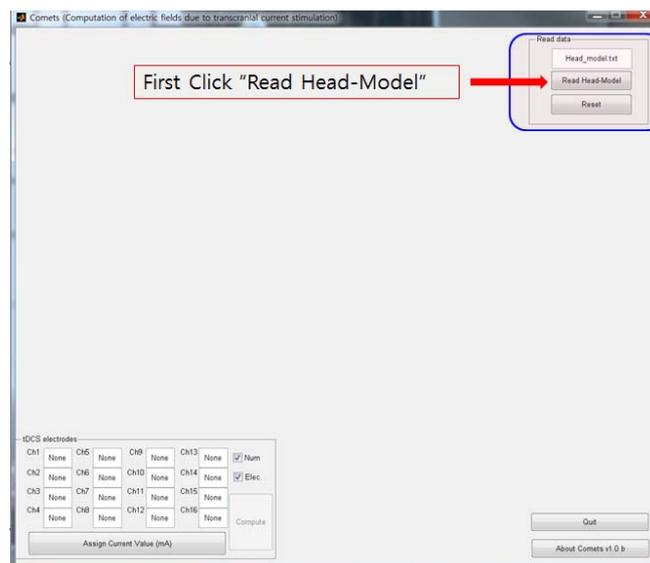


**Figure 3  The initial window of Comets**

# 2. Read Data

➢ Click the 'Read Head-Model' to use the default head-model data.

➢ Then, 3D mesh model of the scalp will appear in the main window.
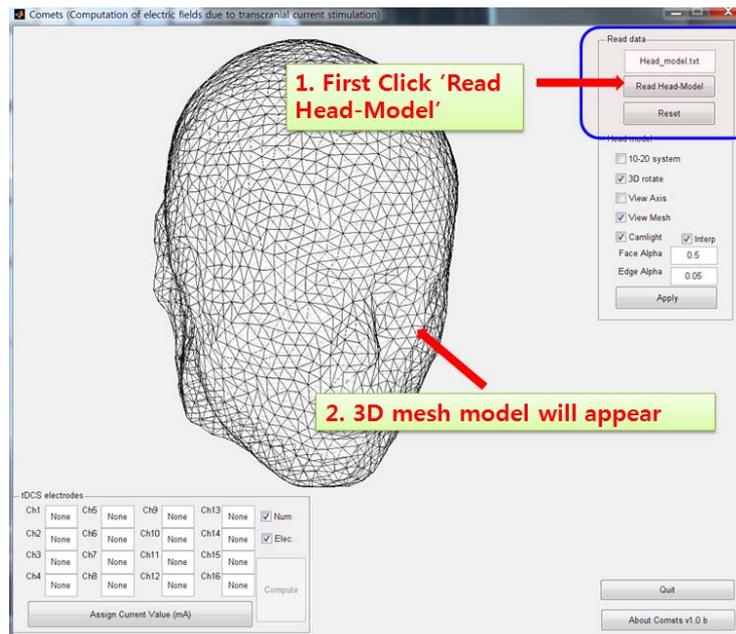


**Figure 4 Head-model information in Comets**

➢ At the same time, a 'Head Model' panel is going to appear. The 'Head Model' panel provides several functions to control visualizations of the 3D mesh model, such as interpolation, light source effect, and so forth.

To use the comets toolbox, you first need to insert the head-model information. Comets provides a default head-model dataset, '**Head_model.txt**', which was extracted from a standard brain atlas. If you want to use an individual head-model, you can import your own data to this toolbox. Please find a separate document file describing the procedure.

# 3. Head model

The 'Head model' panel consists of 5 check boxes, 2 text boxes, and 1 button.
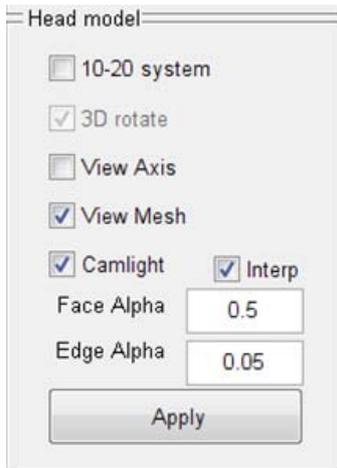
These command functions can change several visualization effects. Each function is explained below:

- 10-20 system : Turn on/off "10-20 system (EEG)" electrodes display.
- Interp : Interpolates the 3D mesh model (default: checked).
- Camlight : Changes light object mode in camera coordinates. if you check this area, 4 light objects are created. Otherwise, only 1 light object is created.
- 3D rotate : Enable (checked) / disable (not checked) '3D rotate' mode
- View Axis : Turn on/off all axis lines, tick marks, and labels.
- View Mesh : Turn on/off the edge shape of the head mesh model.
- Face Alpha : Specifies the transparency of surface image defined by Faces.
- Edge Alpha : Specifies the transparency of mesh image defined by edges.
- Apply : Apply all properties of 'Head model' panel to the 3D head model.
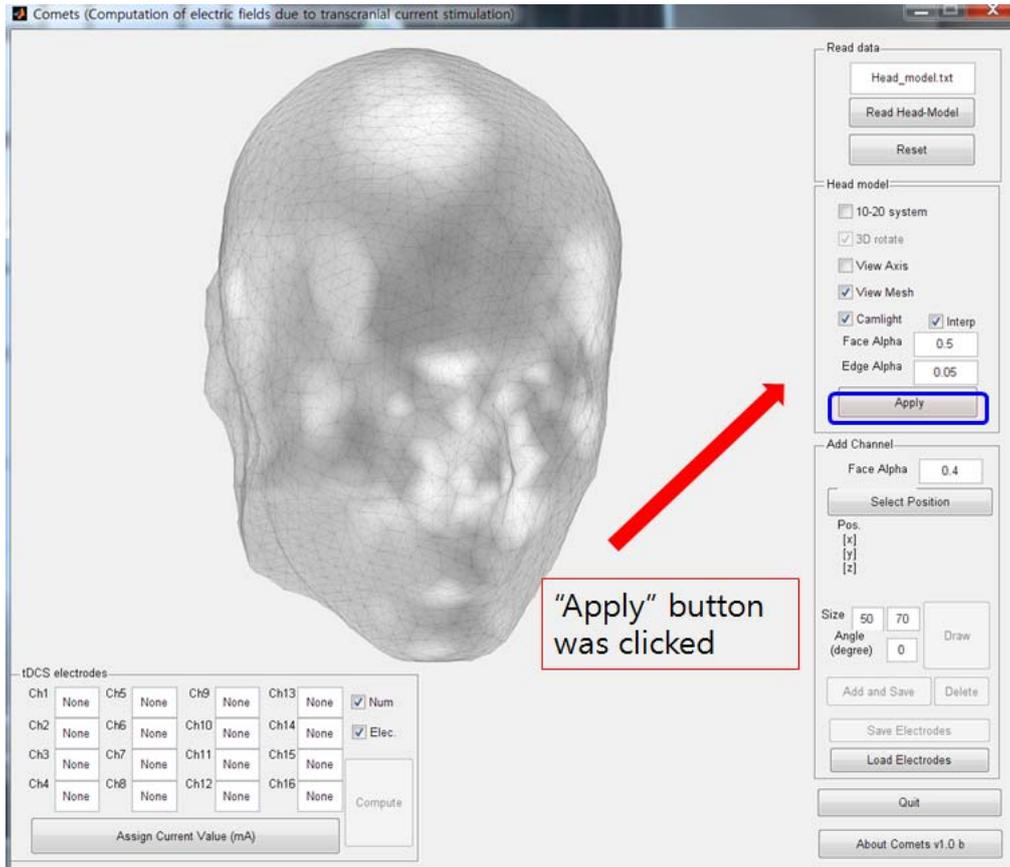
**Figure 5  3D head image after applying conditions in the 'Head model' panel**

The 'Head model' panel controls only the head image (not the cortex image). Until this process, cortex image will not be displayed. After simulating electric fields, cortex image and another control panel will appear. If you set the face alpha value to '0', the head image may disappear. But the information still remains in the toolbox.

# 4. Add Channel

Using the panel of 'Add Channel', users can place the tDCS electrodes on scalp surface. This panel consists of 4 textboxes and 4 buttons to set the electrode information.
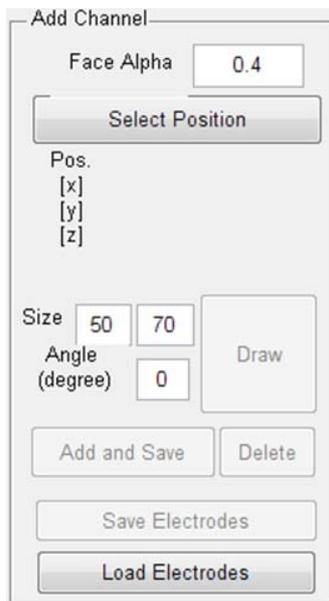
Face Alpha : Specifies the transparency level of the electrode surface image.

Select Position : Changes image mode (see next page)

Size 30 40 : Set the size of tDCS electrode ( X [30] size and Y [40] size), **unit: mm**

Angle (degree): Rotates the electrode around the selected point

Draw : Creates an electrode shape which is a candidate for the tDCS electrode. The information of tDCS candidate electrode will not be saved until the 'Add and Save' button is clicked.

Add and Save : adds and saves information of the candidate electrode. The electrode is mapped onto the scalp surface.

Delete : deletes the information of the added electrode (one by one).

Save Electrodes : saves the selected electrode position. This function will be activated when two electrodes were added.

Load Electrodes : Load a previously saved electrode position.
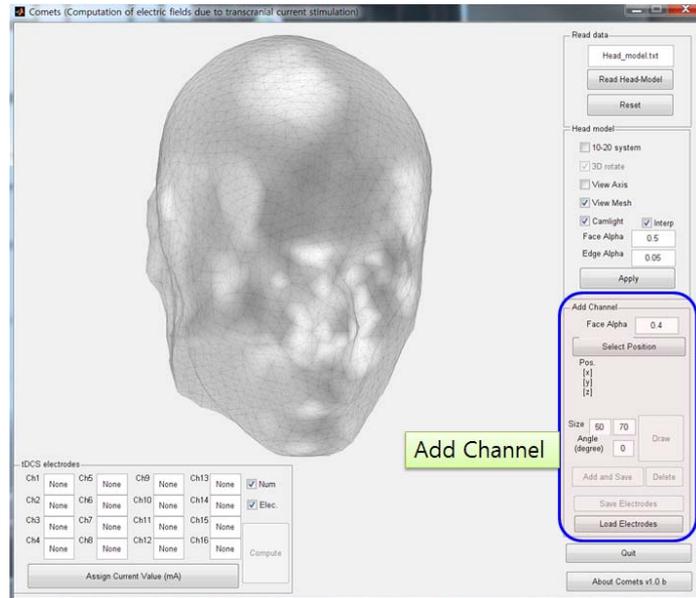
when you click [Select Position], axis image control mode changes from the '3D rotating mode' to 'electrode positining mode'. Then, the button [Select Position] is also changed to [3D Rotation!]. If you want to return to the '3D rotating mode', just click the [3D Rotation!] button again.



**Figure 6  The procedure for determining the position of the candidate electrode**

To attach (place) the tDCS electrode on the scalp, users can press [Draw] button. When [Draw] button is clicked, the electrode surface will appear on the scalp (see Figure 7).
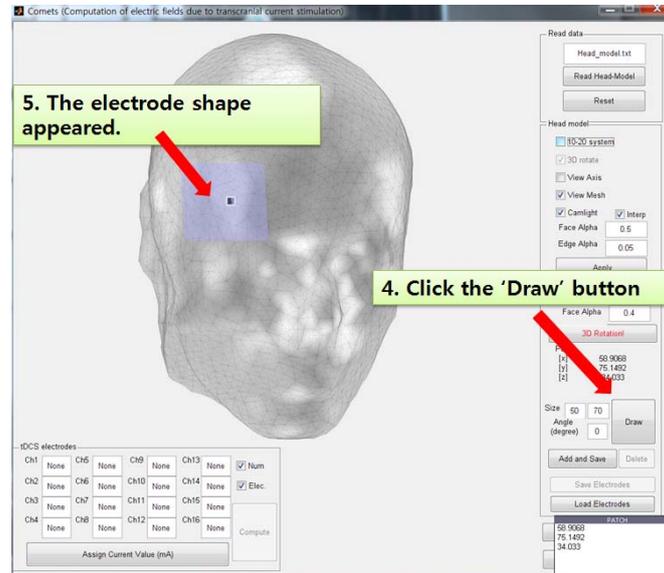


**Figure 7 The procedure for drawing the candidate electrode**

The shape (size, direction) of a tDCS electrode can also be determined by the users. Size of the electrode can be changed by typing values in the 'size' textboxes. The two textboxes represent X-size and Y-size. Electrode diretion can also be set by using 'Angle' textbox. **Unit of 'Angle' is degree** (not radian). Figure 8 illustrates the procedure for locating the position of the electrode.
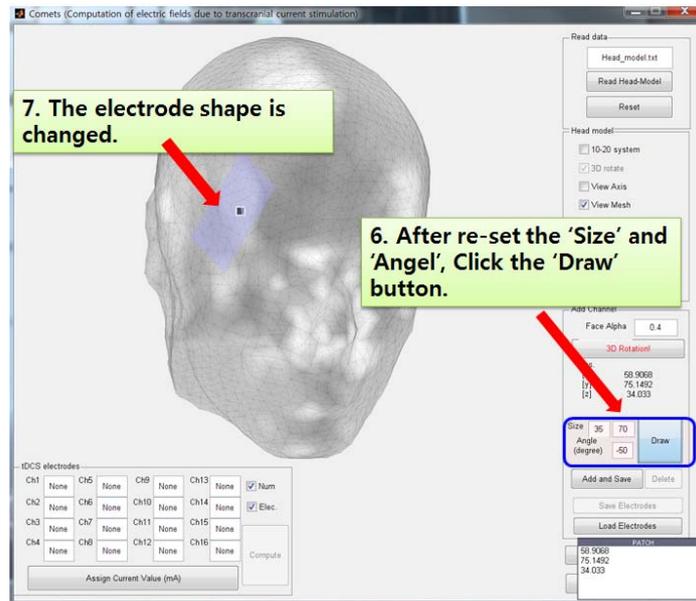
**Figure 8　The procedure for re-drawing the candidate electrode**

If you want to save the information of the tDCS electrode, you can click the Add and Save button.
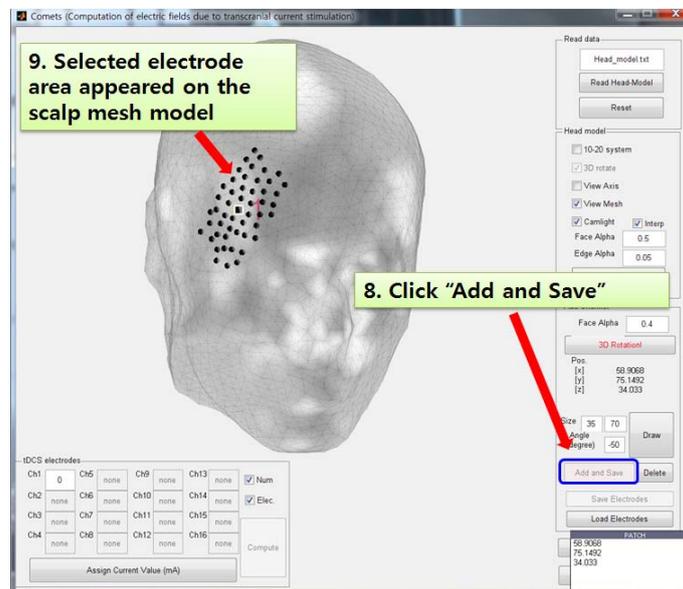


**Figure 9 The procedure of adding a tDCS electrode**

Users need to add an additional electrode. You can change the mode into '3D Rotation' by clicking [ 3D Rotation! ] button (see Figure 11). Then, repeat the procedures #4 ~ #9.
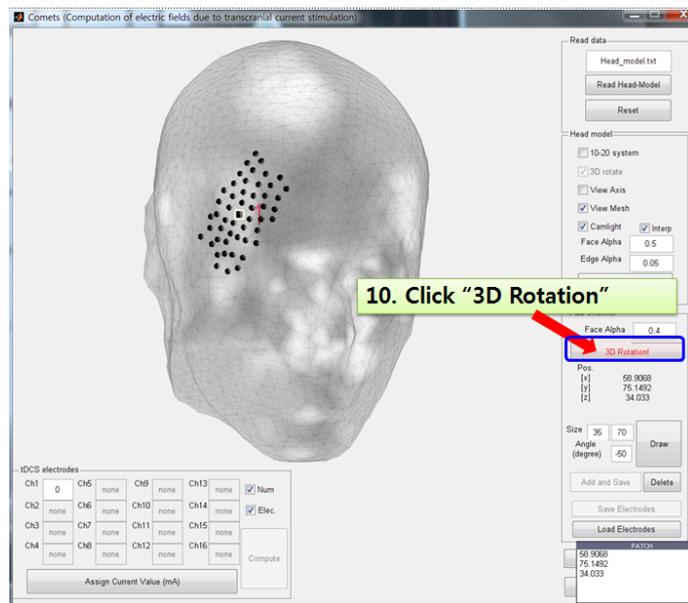


**Figure 10 Changing mode from the 'Select position' mode to the '3D Rotation' mode**
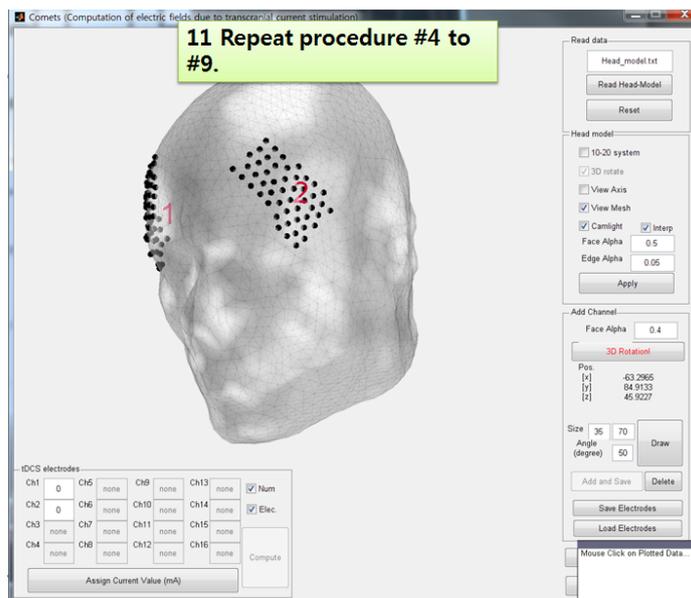


**Figure 11 Two tDCS electrodes were added to the head model.**

# 5. tDCS electrodes

The 'tDCS electrode' panel is used to assign the input current values to the tDCS electrodes and to estimate the electric field distributions on the cortical surface. Users need to input the current value of each electrode in the panel. After that, pressing the 'Compute' button to calculate the electric field distribution using FEM (Figure11). Process of calculating FEM is shown in the command window of Matlab (Figure 12).
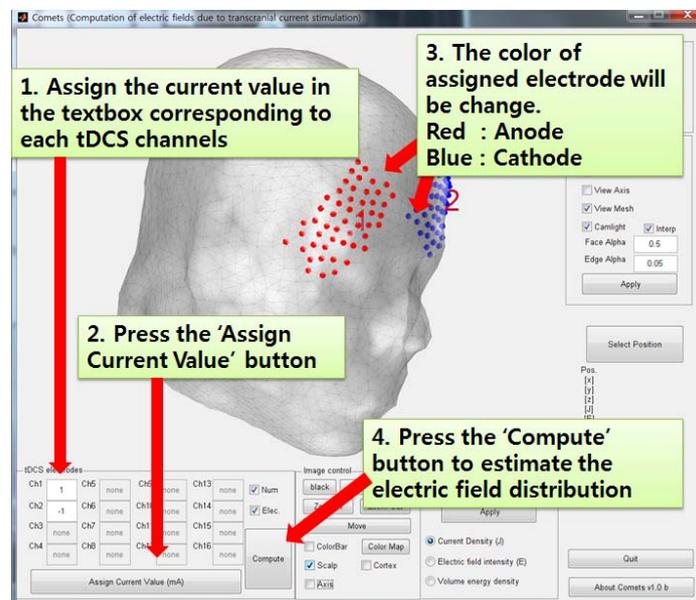


**Figure 12 Procedure of assigning currents and executing an FEM solve**

This panel includes the two checkboxes [☑ Num, ☑ Elec].

If ☑ Num is checked, the electrode number is displayed on the scalp.

If ☑ Elec is checked, the electrode locations are displayed on the scalp.

**Figure 13 The command window of Matlab while the FEM solver is executed**

# 6. Cortex model

After the FEM calculation, a 'cortex model' panel will appear. In this panel, users can modify the 'face alpha' of the cortex model, and select the quantities that users want to visualize on the cortex surface (Figure 13).
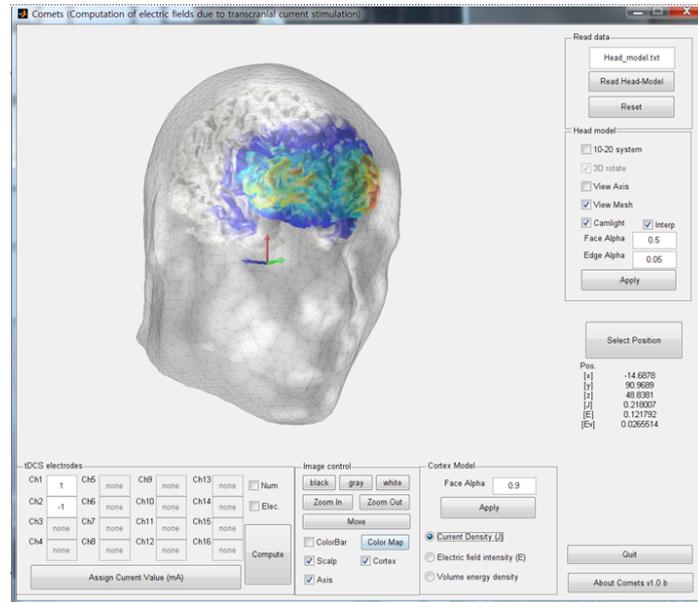


**Figure 14  The resultant image**

# 7. Control the result images

Finally, users can control the resultant images (head model, cortex model, and electrodes) in the 'Image control' panel which consists of 7 buttons and 4 checkboxes (Figure 14).



**Figure 15 Image control panel**

Three buttons, '**black:** black', '**gray:** gray', and '**white**: white', can switch the background color. Two buttons, '**Zoom In:** Zoom In' and '**Zoom Out:** Zoom Out' can be used to change the model scales. The '**Move:** Move' button can be sued to move the image in the main window. The 'color map: Color Map' button allows to change the color-map using the color-map editor (a Matlab function, Figure 15 & Figure 16). The additional 4 check boxes can be used to show/hide each model image.
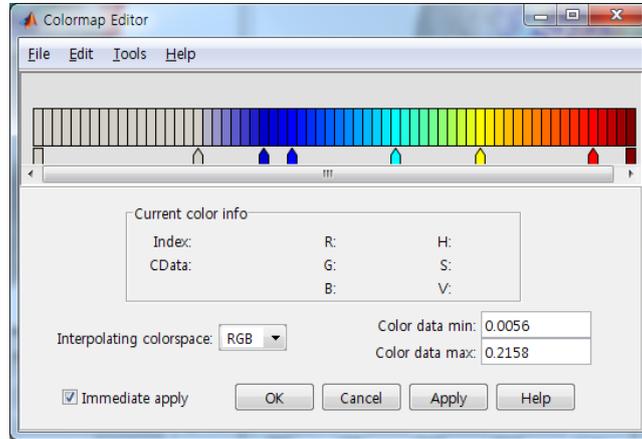
(a) Pre-set value
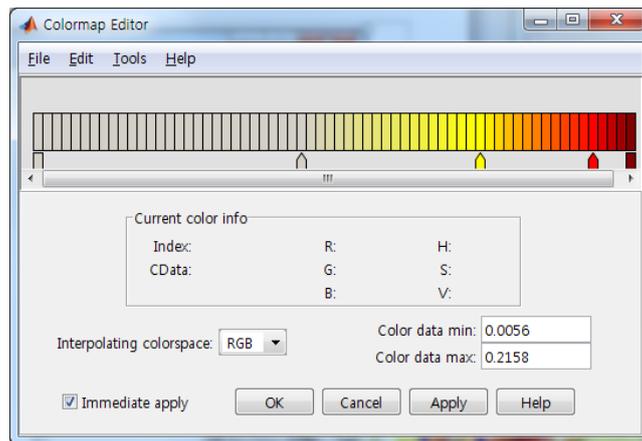


(b) New value

**Figure 16 Color map editor**
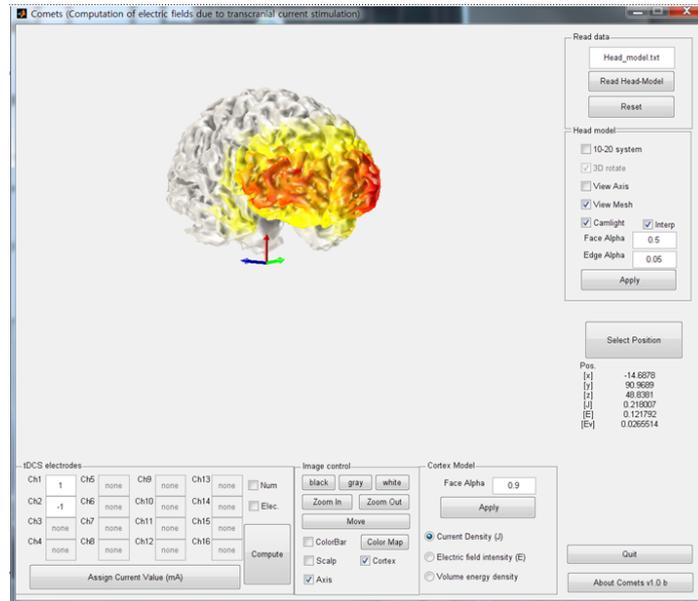
**Figure 17 Image with the modified color-map**

ASCII-format output files that can be imported in a commercial 3D visualization program Tecplot® (Tecplot Inc., WA, US) or a free 3D visualization program MeshViewer (http://mview.sourceforge.net) are automatically generated in the main folder of the toolbox after each finite element analysis (cortexfield.tec and cortexfield.ply)

# Acknowledgement

The Comets toolbox was developed in the Computational Neuroengineering (CoNE) Lab at the Hanyang University, Korea. Prof. C.H. Im first proposed the idea of Comets toolbox, coded the main FEM solver, and directed the development of Comets toolbox. Y.J. Jung designed the GUI modes and implemented the all Matlab functions. The members of CoNE lab helped to fix the bug and advised to modify the toolbox.
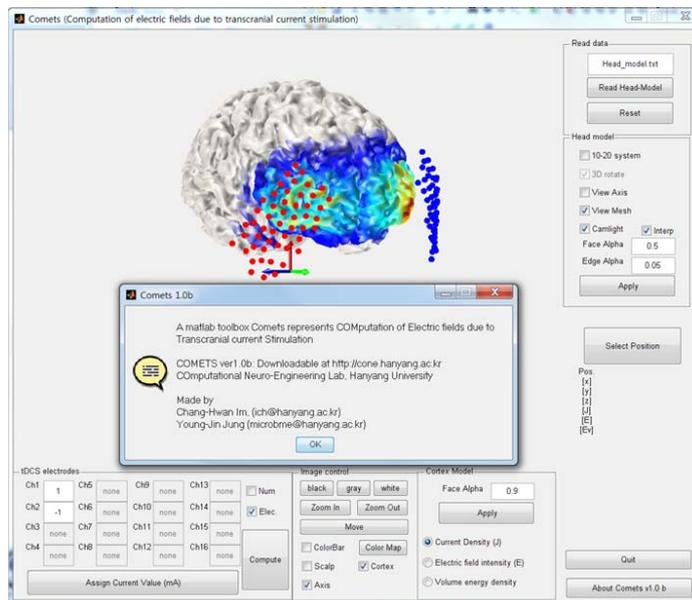
*Thank You.*

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