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Users manual

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Introduction

janus3D is a MATLAB based toolbox for coregistration of individual 3D head models of subjects wearing an EEG cap and individual MRIs. In addition it features smart selection and texture based automatic detection of EEG electrode positions and provides highly accurate EEG sensor locations for later source reconstruction. janus3D provides you a fast GUI based workflow to get the most accurate EEG electrode positions out of your subjects 3D head models. Furthermore janus3D includes tools for building individual templates and image masking.

Requirements

MATLAB (2015a or later) including:

Image Processing Toolbox

Computer Vision System Toolbox

Fieldtrip Toolbox (available on <http://www.fieldtriptoolbox.org/>)

Basic aspects on working memory and OpenGL

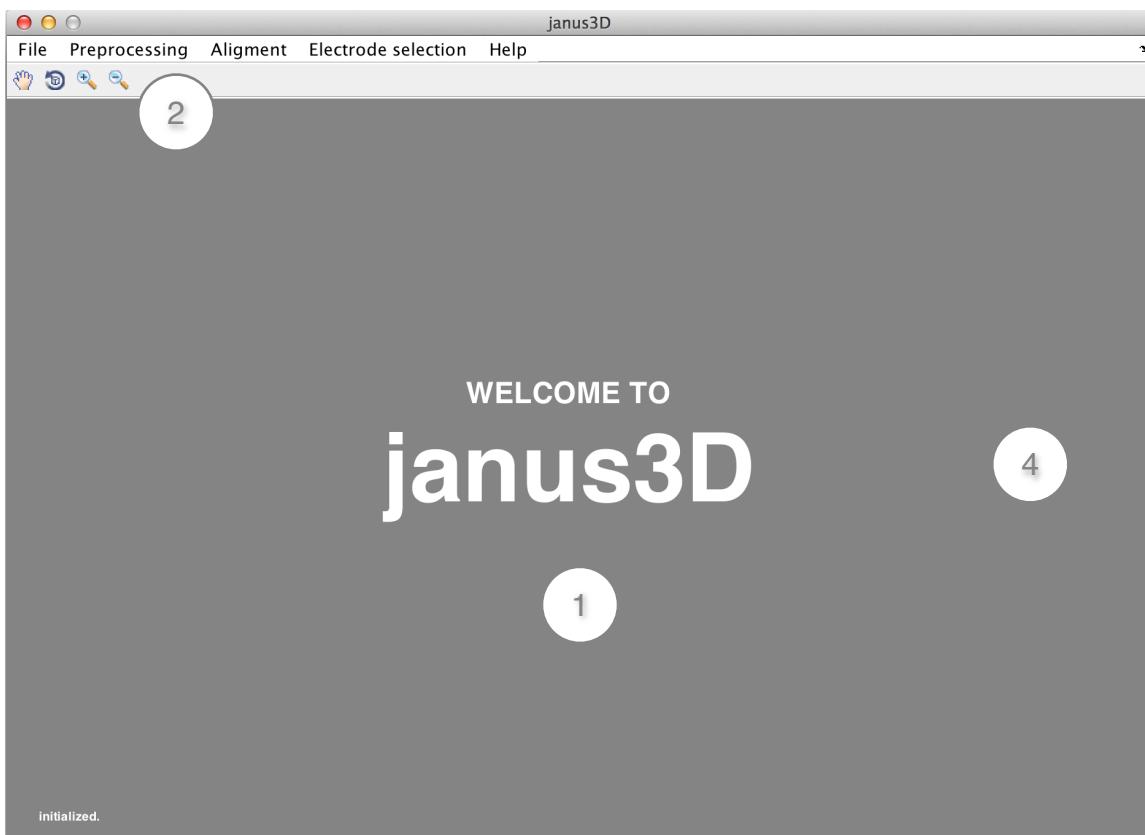
janus3D is performing a lot of highly working memory consuming operations. Due to this fact you should assure that your operating system dedicates enough RAM to MATLAB. A very minimum of 4GB system working memory is required to make janus3D run properly. To make all graphical operations as fluent and all renderings as detailed as possible, OpenGL support is advantageous. Notice, that the used 3D operations are performed on high resolution 3D models with an amount of hundreds of thousands 3D points. Most variables within janus3D are stored as global variables, meaning that they remain in your working memory until MATLAB is closed or they are deleted. Global variables can be accessed from your base work space, but must not necessarily appear there to be assigned. Nevertheless they will be blocking parts of your working memory. janus3D will remove all global variables at each start and also if you close janus3D by using the ,done & exit' button or by deleting the GUI window. But you should keep in mind, that if janus3D crashes the global variables might remain stored in your computer's working memory. You easily can delete them by using the ,clearvars -global' or ,clearvars -global variablename' command and access them by typing ,global variablename'.

Getting started

To get started with janus3D add the janus3D folder to your MATLAB search path and type one of the following commands into your command window to make the GUI show up:

```
,janus' - ,janus3D' - ,j3d'
```

Main GUI window



1 - operation window

The operation window is the large field in the center of the janus3D window, now displaying 'Welcome to janus3D'. It adapts its output to current processing steps and displays all outputs of ongoing operations. Therefore the operation window is the playground where all of your work is done.

2 - toolbar

The toolbar is located in the top left corner of the janus3D window and enables you to perform basic operations to the operation window. You can pan, rotate and zoom in and out within each figure displayed by janus3D in the same way you are familiar with common MATLAB figures.

3 - main functions

At the top side you find all of the main functions that janus3D provides. Selecting ‚File‘ makes janus3D expand all session relevant features like saving or loading janus3D sessions, as well as the ‚Photo Masker‘ and ‚Template Builder‘ tool and the preferences, where you can set your default EEG cap template. ‚Preprocessing‘ includes all relevant steps for preparing the MRI and the 3D model for later steps ‚Alignment‘ and ‚Electrode selection‘. Clicking the ‚Alignment‘ button will expand functions used to align and correct the position of the 3D model relative to the MRI. Inside ‚Electrode selection‘ functions for manual and texture based electrode selection, automatic labeling and displaying of selected electrodes are included.

All functions that can not be used, because prior function results are missing, are grayed out and will be enabled, when prior results are present.

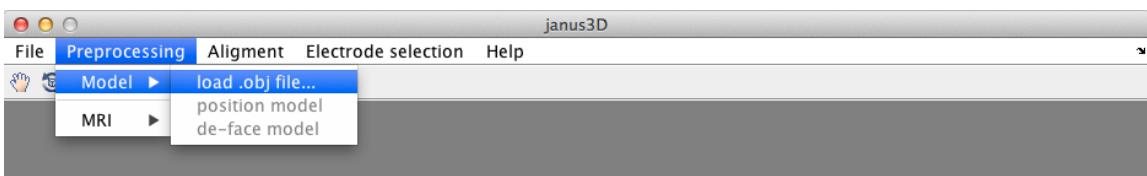
4 - function specific sub functions

Some main functions provide you another couple of sub functions. To avoid graphical overload all relevant sub functions are displayed due to a call to the related main function and remain invisible the rest of the time. Sub functions are displayed on the right hand side of the janus3D window.

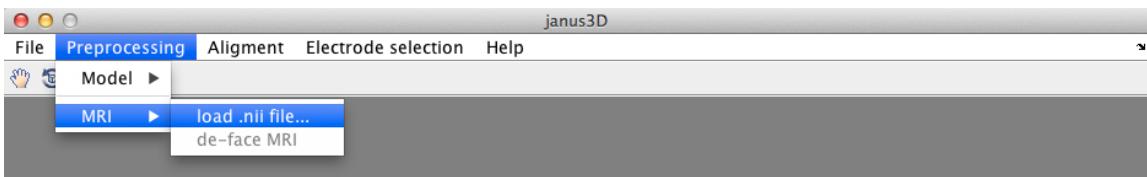
Workflow

- **loading model and MRI files**

To load a desired file just click on the load button inside the 'Preprocessing' section and a dialog box emerges in which you can select the desired file. This might take several minutes, depending on which computer setup you use. Wavefront Object Files (.obj) are supported to have vertex coordinates, vertex texture coordinates and face indices. The import of vertex normals is not supported and it is also not recommended to import Object files containing vertex normals.



In case of loading NIfTI files (.nii), janus3D directly extracts the outer surface (scalp) and creates a 3D model out of it. This function is based on the `ft_read_MRI`, `ft_volumesegment`, and `ft_prepare_mesh` functions implemented in Fieldtrip.

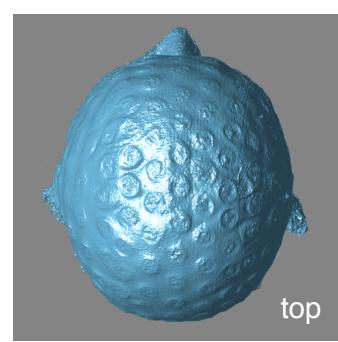
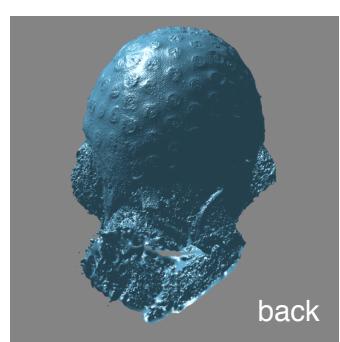
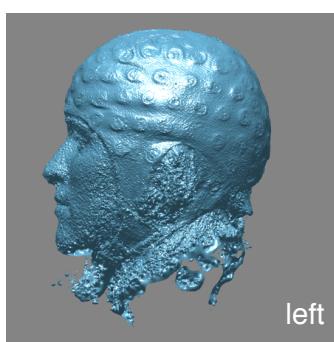
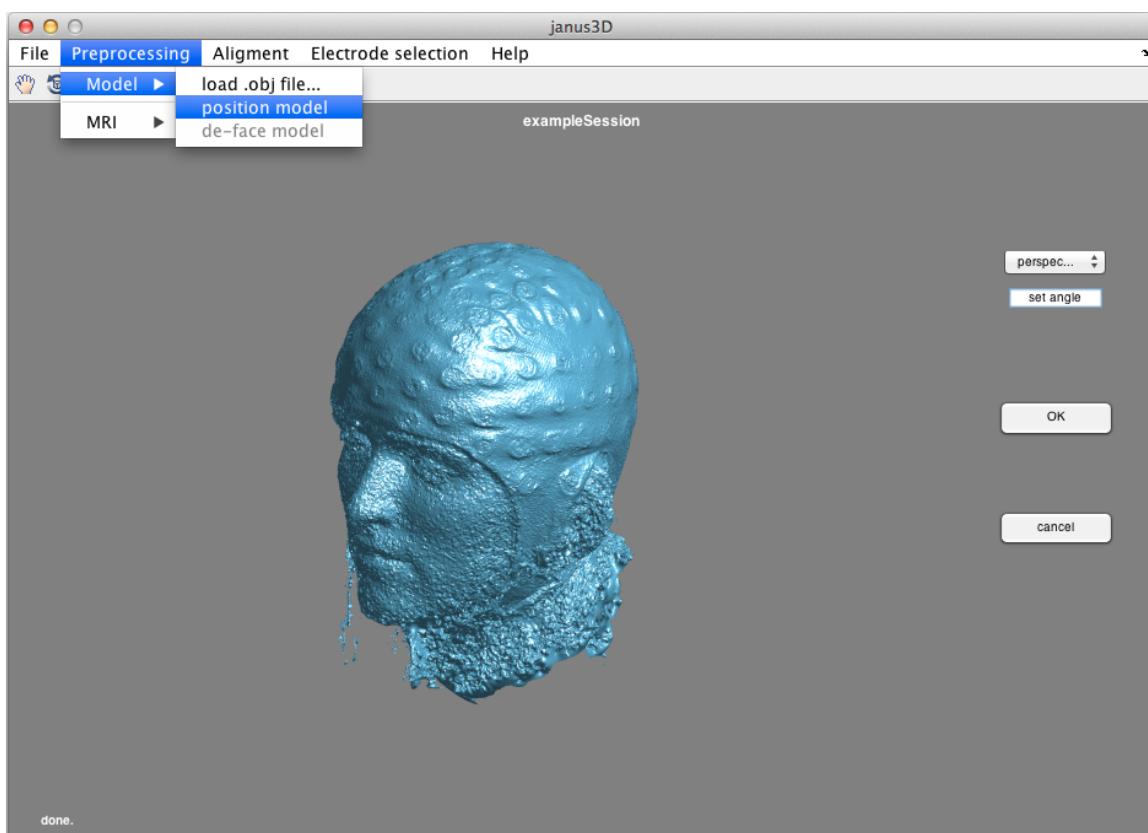


- **position model**

The first step in preparing the individual 3D models is to do a pre-orientation into MRI space, meaning the x-axis pointing from the left ear to the right, y-axis pointing from the back to the front and z-axis pointing from bottom to the top. To get a proper performance you need to manually rotate the model based on a 3 side view approach. Select Preprocessing -> Model -> position model select the left side view and make the model upright in dependency of the horizontal line. This can be done by clicking on left side appearing in the drop-down menu within the related functions field. The view-angle changes and now you can type your desired angle into the editable text box and press enter. If the model is upright, meaning that the tip of the nose and the inion point are horizontally aligned, then proceed to the top side view-angle in the drop-down menu. Rotate the model in the way that the tip of the nose points to the top of the screen and the ears are

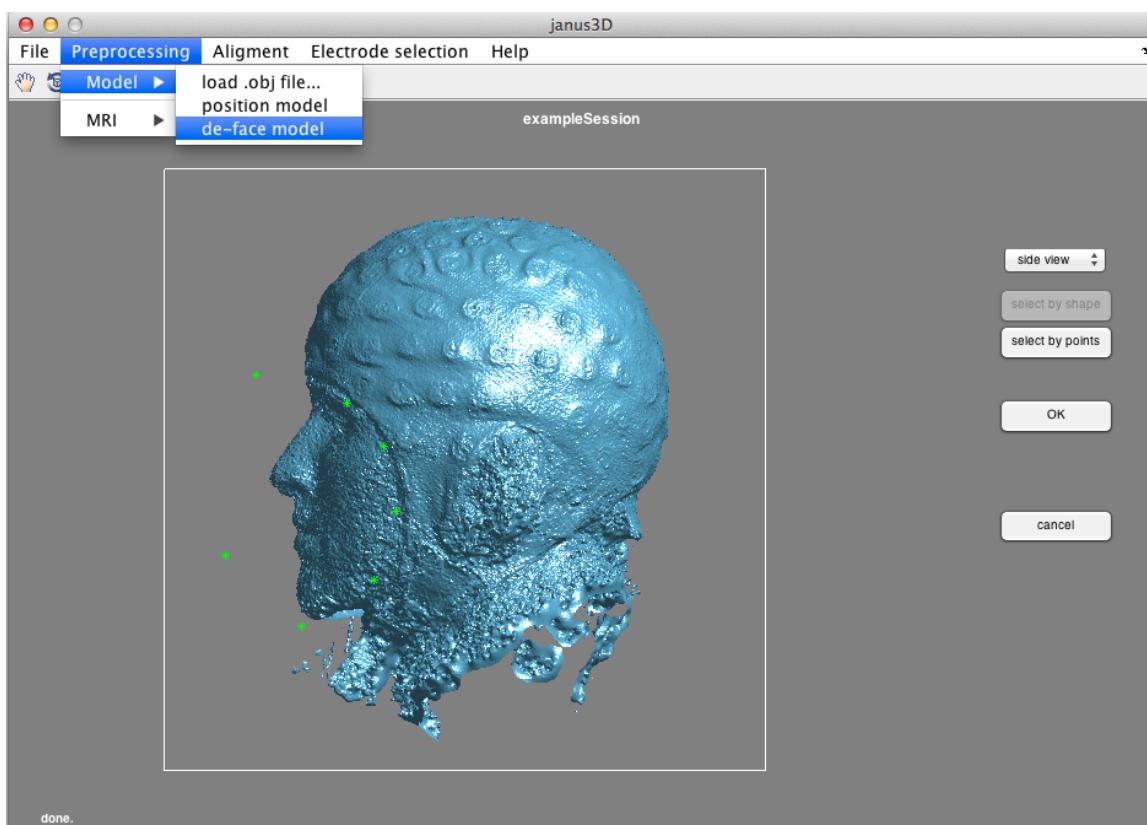
aligned in a horizontal line. The last step is to select the backside option in the drop-down menu and making the ears horizontally aligned. If you now click on perspective, the model should look to a point to your left. There is no specific need to proceed in the mentioned way. You can choose your own sequence of steps that is most comfortable for you but the resulting orientation of the model is imperatively necessary.

If you aligned the model properly just click the 'OK' button and all changes will be applied to the model.



- **de-facing**

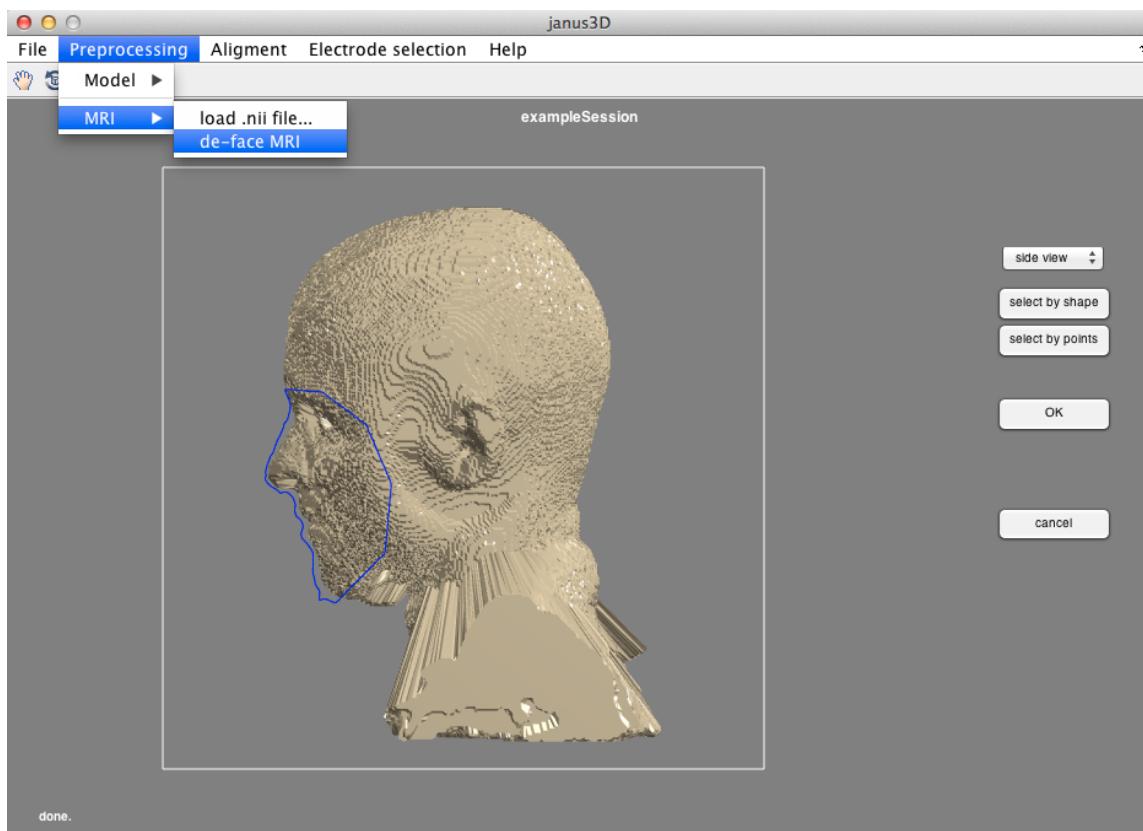
After you positioned the model or loaded the MRI, a button called ,de-facing' located in Preprocessing -> Model/MRI will be enabled. De-facing in that sense means that the face of each model will be selected for later iterative closest point matching. The easier way to go is to de-face the 3D model first and do the de-facing of the MRI afterwards. No matter what you do first, you will find two relevant buttons on the function related functions field. The first time you do the de-facing, the ,select by shape' button should be disabled. This is because the ,select by shape' option enables you to select the second face, based on the selection of the first one, so if you did not select a face so far, the ,select by shape' button would make no sense and is therefore disabled. When you now start the de-facing the first time you have to select the face by a selection of points forming a frame surrounding your desired selection. Just click on the ,select by points' button and you enable the point selection. Make a few points that define the outer borders and then click the button again to confirm your selection. There is no need for being highly accurate because janus3D selects the face based on all points of the model that were in line with the selection. You can make your face selection visible by selecting ,perspective' from the drop-down menu above. However the selection itself can only take place in side view. After you finished the selection and clicked ,select by points' again, click onto the ,OK' button to finish this step. Below a whole face selection is shown. In some cases a selection from the eye brow to the upper lip is more sufficient,



due to the fact, that the upper part of the face includes more morphological invariant parts, when matching with the MRI.

Assuming you already selected one of the two faces (Model or MRI) you can select the second one by clicking on the 'select by shape' button which now should be an available option. After clicking the button your mouse cursor changes to be the shape of the face you selected before. Now you only have to fit the shape to your model and click the left mouse button. Afterwards just press the 'OK' button and your selection will be applied. You might have noticed that the shape might be slightly in different scale and also in different rotation. By using your mouse wheel you can freely rotate the shape and by pressing and holding 'ctrl' on your keyboard, while using the mouse wheel you can scale your shape until you release the 'ctrl' button. With this in mind you are able to perfectly fit the shape of the first model to the second and to finish this step press 'OK' as usual.

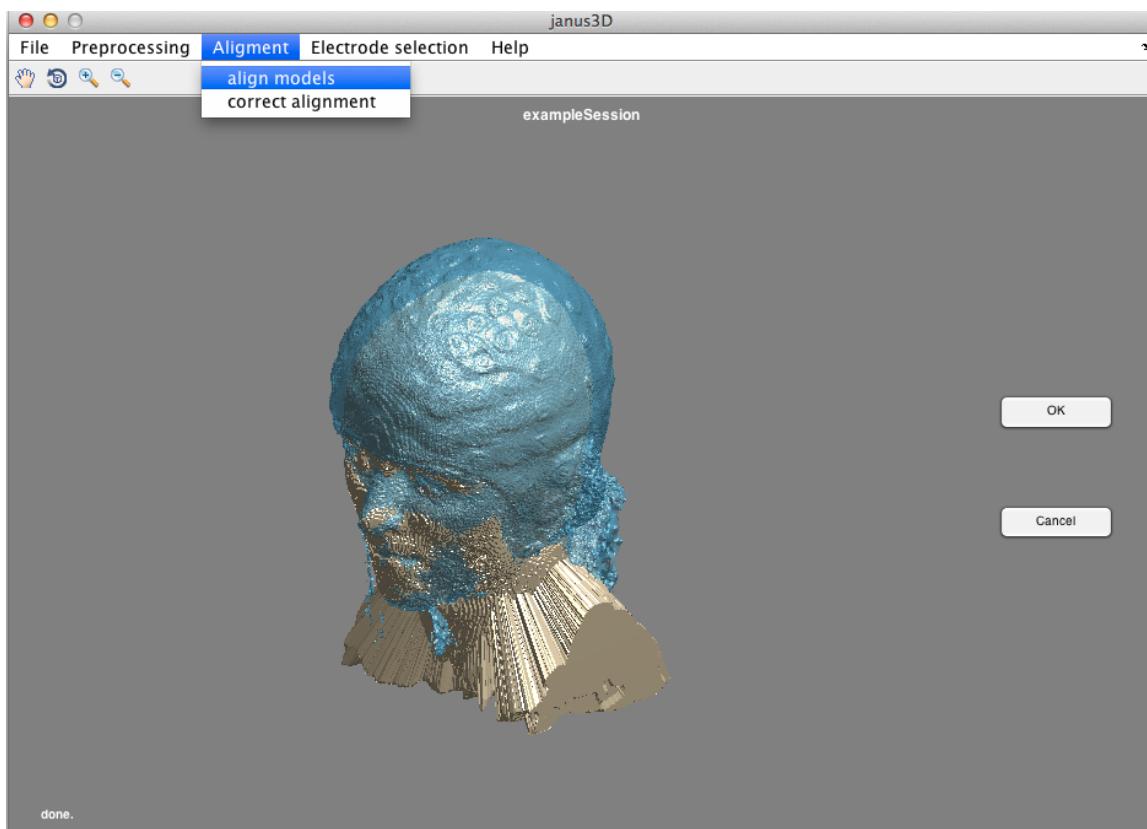
Notice that the more similar both selections are the more accurate your later coregistration of both models will be. Also notice that you should try not to include parts of the face shape that might differ in a strong fashion. For example a chin-beard that is present in the model but not in the MRI could disturb your later face aligning and therefore should be excluded from the selection. In that case it would be a good idea to select the face from the lower lip upwards.



• aligning Models

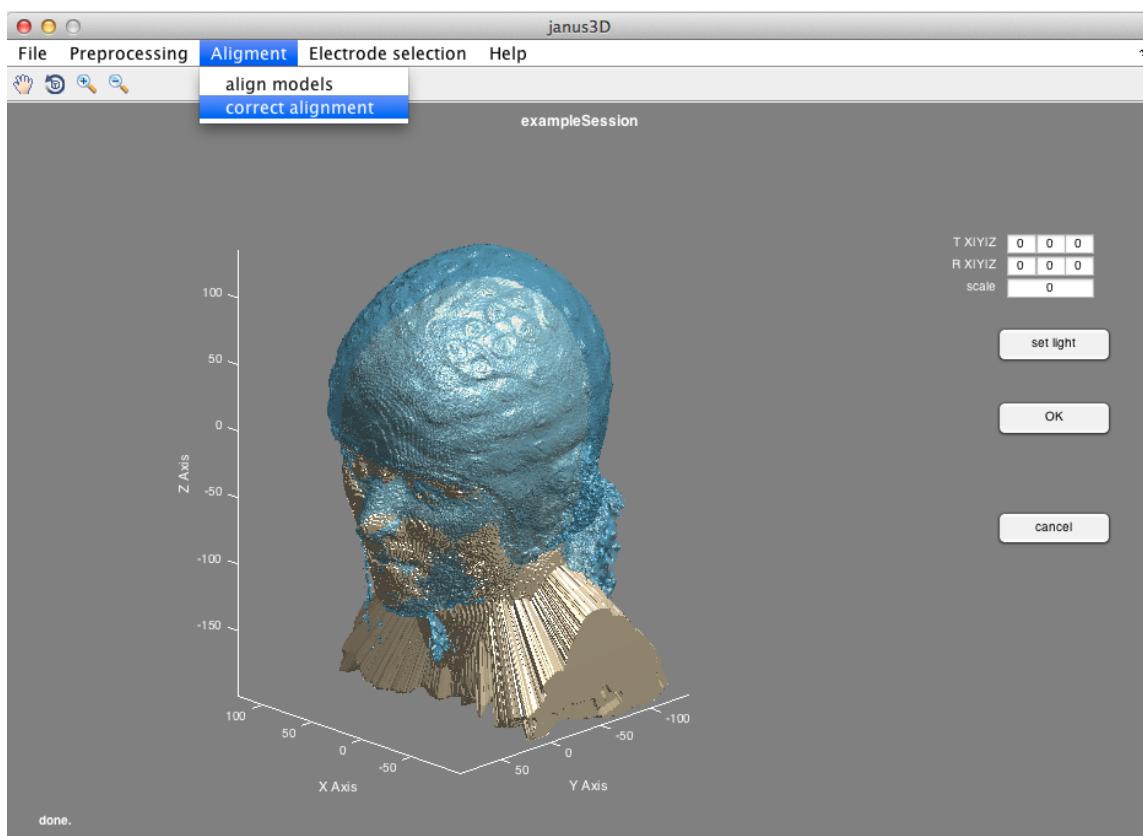
If you de-faced both of your models, janus3D will recognize that and enables the ‚align models‘ button for you. After clicking on it janus3D will ask you to select the algorithm you want to use for the face alignment. Most of the task can be done by not changing the preselection which is ‚Point-to-Point‘, but if you have a very flat face surface you should consider selection ‚Point-to-Plane‘. After computing the alignment using the iterative closest point algorithm, the transformation matrix that was used to transform the models face to the MRIs face is applied to the whole model.

The result will be shown in the operation window and the only thing you need to do is to confirm that the step was finished. In case you are not satisfied with your face alignment, you might go back to the de-facing and maybe you will find some parts that are not comparable (e.g. beards). Keep in mind that due to the rotation of the alignment the position step might also be necessary to be done again. If janus3D fails more often to align your models properly, you might proceed with the step that is mentioned below.



• correcting Models

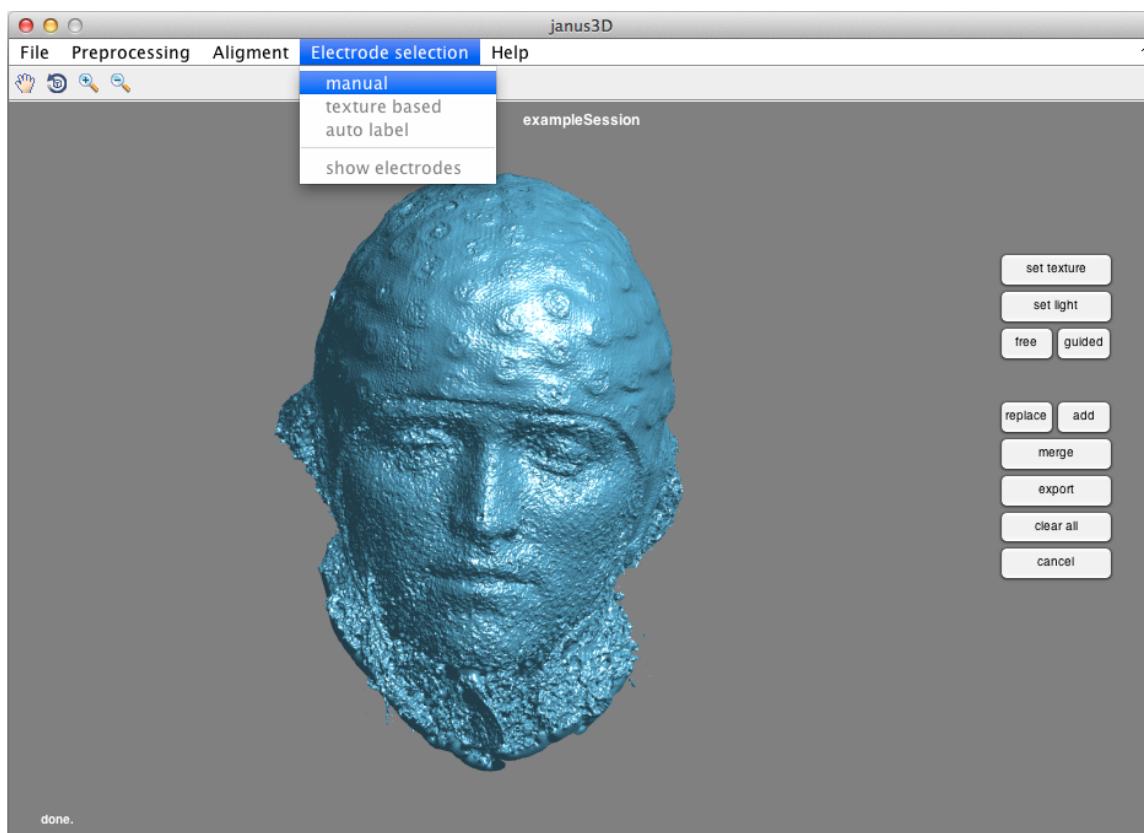
After you aligned the models together you will have the option to correct the alignment manually. Sometimes it can happen that the alignment looks strange or is slightly wrong. This can be caused by bad models or bad face selection. You now have the option to do the face selection again or to align the models manually. The latter one can be done using the function field of the ‚correct alignment‘ function. It offers you seven different editable text boxes to correct translation, rotation and scaling. The upper row of text box array lets you translate the model in all three dimensions, based on the units from the coordinate system which normally should be millimeters. The second row of the array enables you to rotate the model around the three axes of the coordinate system. The last row which only consists of the field ‚scale‘ allows you to scale the model relative to 1. So typing ‚2‘ into the editable text box would cause janus3D to double the models size. After you did the correction you wanted to do just click the ‚OK‘ button and all changes will be applied to the model.



• manual electrode selection

If you want to select your electrode positions manually you can do this by clicking the ,manual‘ button inside the ,Electrode selection‘ field of the main functions section. If you previously have selected a texture file belonging to the mesh, janus3D will automatically apply the texture to mesh. If you did not you will notice two buttons to appear in the sub functions section. The button ,select texture‘ will open a new window where you now can select the related texture file. Notice that only JPEG texture files are supported so far. If you did a selection, janus will automatically apply the texture to the mesh. If you do not have any texture files or you want to select electrodes without textures you can do this as well on the untextured mesh. To support your selection process anyway janus3D enables basic cam light. You can change the position of the cam light by clicking ,set light‘ This causes janus3D to change the lights position to your current viewing angle.

To support your selection process furthermore, janus3D can advice you to select the electrode positions in a specific order. Clicking ,guided‘ will evoke janus3D to display the next electrode to be selected according to the template file, you might have set in preferences. If you did not select any template file janus3D will ask you to either select a .txt or a .mat file (n x 1 cell array) including electrode labels. Notice, that the electrode labels need to be in the form of one per line. The electrode that should be the next one to be selected will be displayed right below the ,guided/free‘ buttons. You also can choose the ,free‘ selection, meaning that if you click onto the head surface a dialog box will appear asking you for the name of the selected point. This especially is useful for



selecting points like nasion or tip of the nose, etc. Points determined by free selection will be stored in a different way than points from guided selection and can not be used for projecting them onto the MRIs surface.

Have you finished your electrode selection, press either ‚add‘, to add the selection to previous selection or replace to replace the previous selection. Clicking ‚merge‘ will merge free and guided selection so that both point clouds are stored as they were selected by guided selection and therefore will be projected to the MRIs surface.

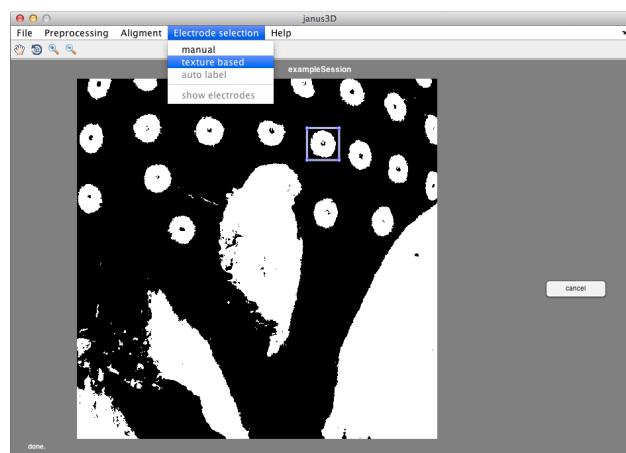
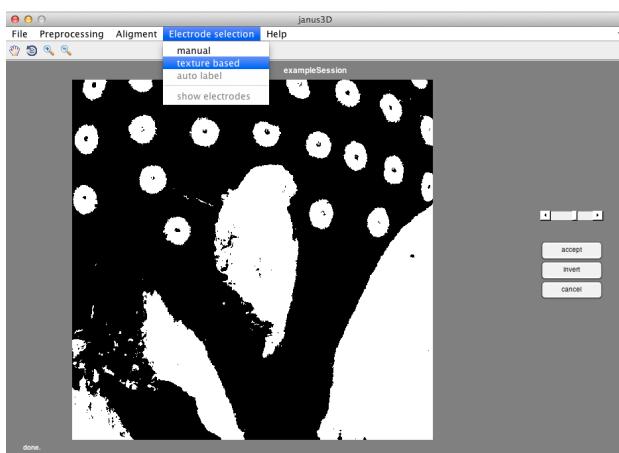
You can directly save your electrodes to a separate file using the ‚export‘ button. This causes a saving dialog to pop up, which asks you to choose path and filename where your selection should be saved. Or you might want to clear all selected points, which easily can be done by clicking ‚clear all‘.

• automatic electrode selection

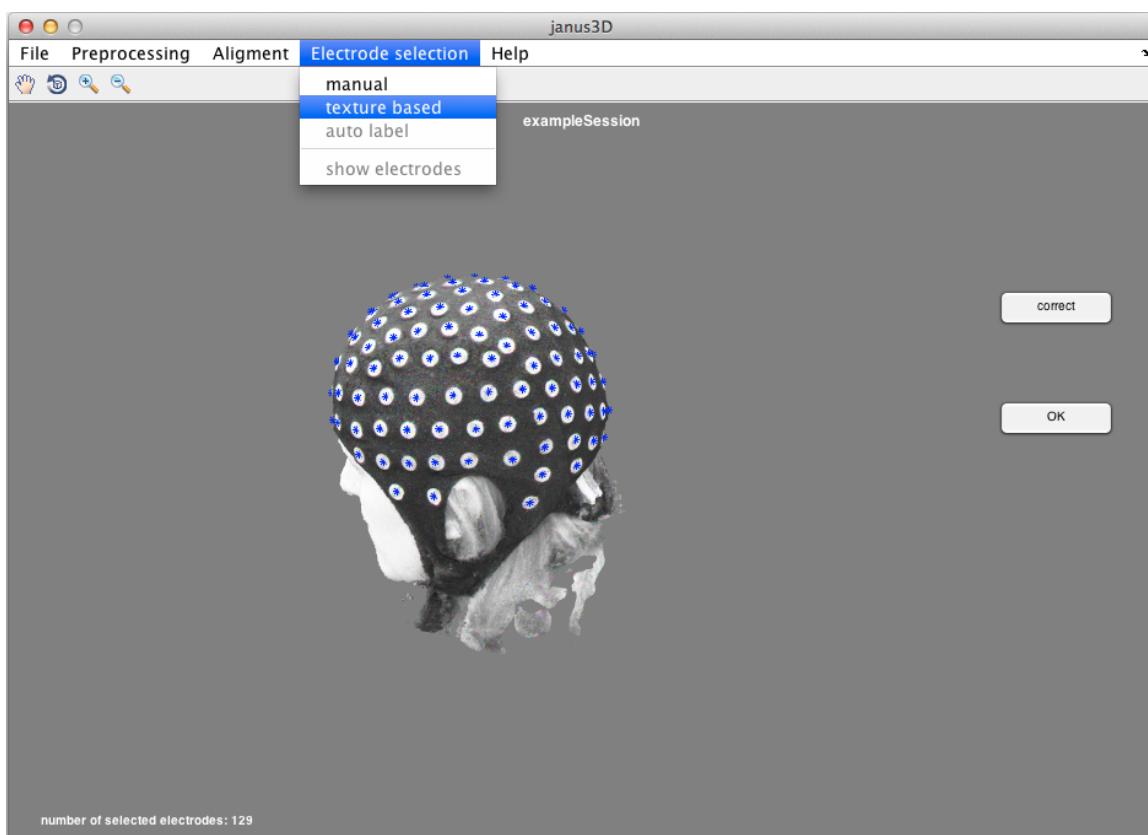
The automatic electrode selection can be initiated by clicking the ‚texture based‘ button from the main functions section. This function selects electrode positions based on the texture information you provide janus3D. If you do not have selected any texture file so far, janus3D will ask you to select a texture file by showing a file selection dialog.

If you have preselected a texture this dialog will not show up. Instead the selection process will start immediately. Notice that only if the contrast between electrodes and their environment is big enough, the automatic detection can be successful. You can adjust the contrast value using the slider and invert it using the ‚invert‘ button. Electrodes are assumed to be white circles so for selecting any dark regions use the inverted images.

After clicking ‚accept‘ you will have to predefine a ‚typical‘ electrode. For this propose a blue rectangle will show up with which you select a typical electrode. Drag and drop the rectangle over an electrode and resize its frame to hem the electrode completely but not touching another



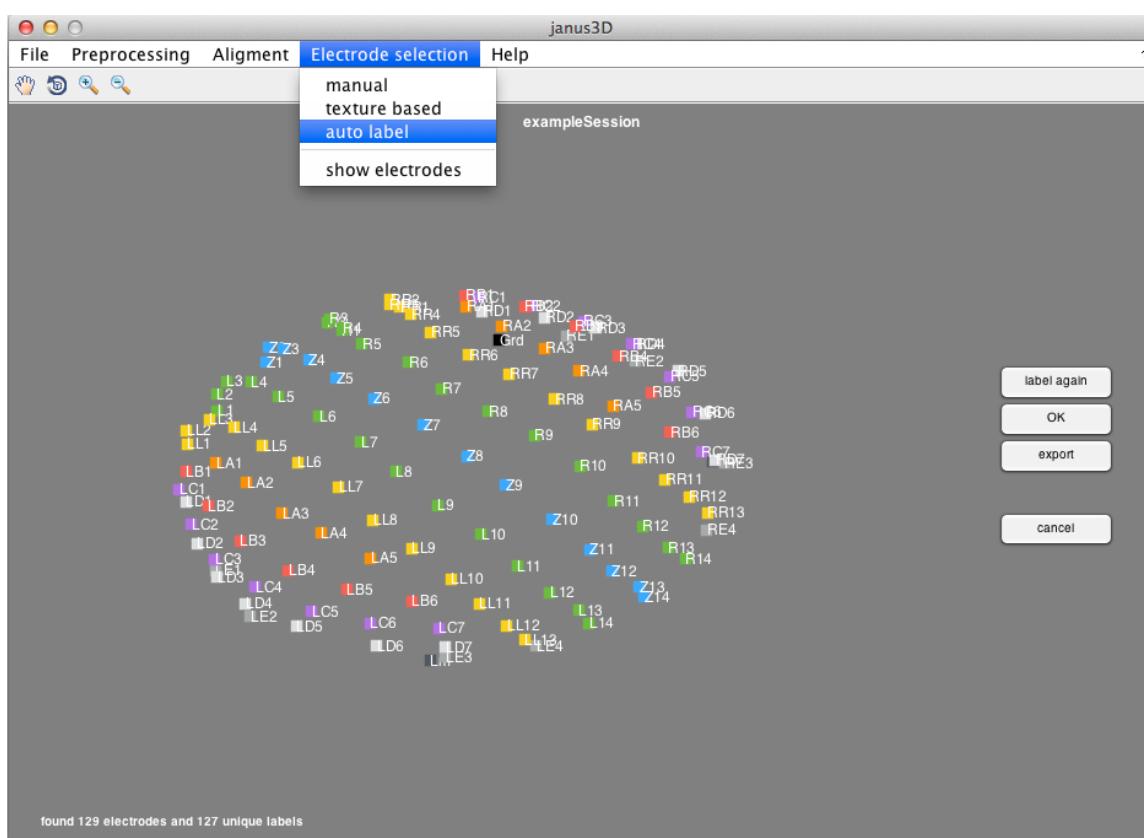
electrode. Afterwards just double click the rectangle and the automatic detection starts. After a few moments (depending on your computers performance) the process will be finished and shows its results. You will see a textured mesh with all centers of the electrodes marked in blue. Also an output to the command window will tell you how many electrodes janus3D found. If you find the number of detected electrodes or some positions to be wrong, just check the model by visual inspection. By clicking the 'correct' button, you will start the manual correction. By left clicking on some point of your textured mesh an electrode will be added at this point and by right clicking to any electrode, this electrode-point will be removed. When you finished your selection and correction press the 'OK' button as usual.



• automatic electrode labeling

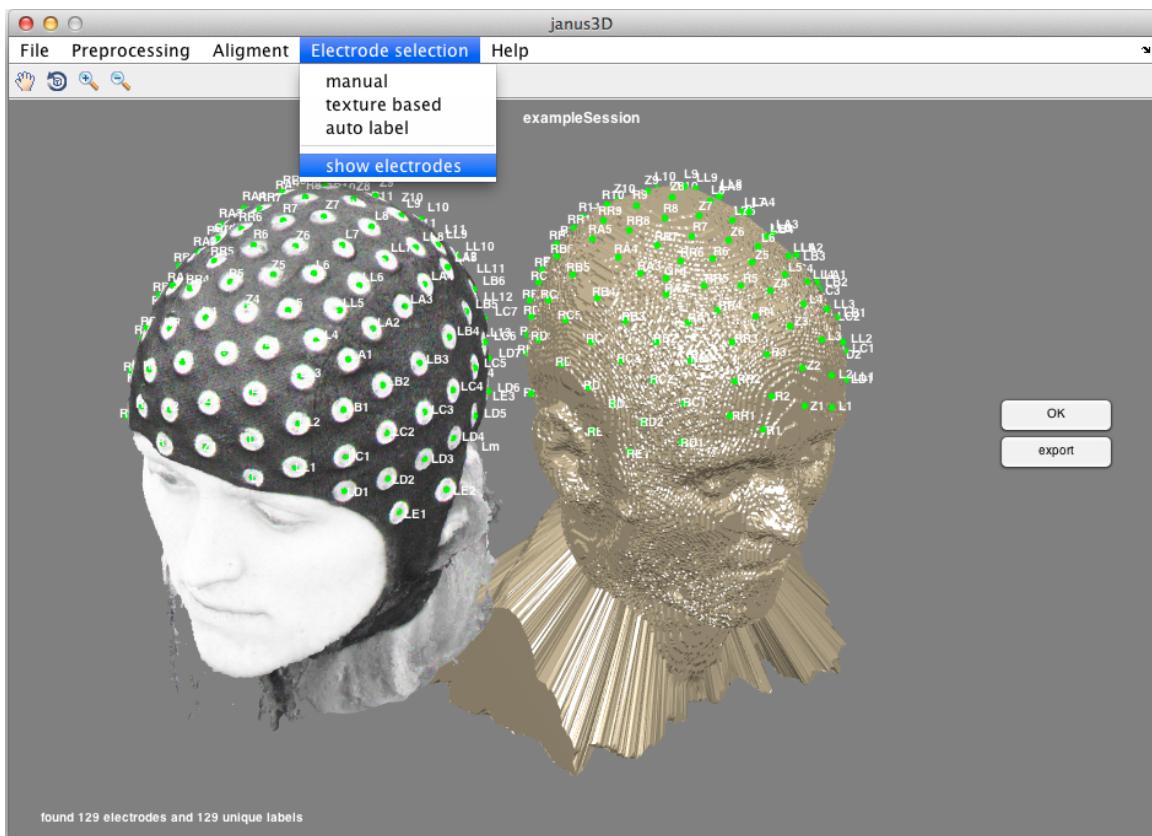
Automatic electrode labeling might be necessary if you selected your electrode positions by automatic detection or if you selected them manually but you ignored the guideline that janus3D provided you. By clicking 'auto label' electrode points will be labeled according to the selected template file. The algorithm finds the most plausible solution to fit the selected points to the template points and labels them accordingly.

After the processing is done the results are shown as a color coded map of labeled points. You can easily inspect the accuracy by first checking the color codes (same color within the same line makes it very likely to be the correct selection) and afterwards checking the labeling. If you find something wrong you can click on the particular electrode and your selection as well as a drop-down menu will appear at the sub functions section. Now you can choose the correct label from the drop-down menu and the labeling as well as the color code will be applied to your electrode net. Once you finished your selection press the 'export' button to export your electrodes directly to a MATLAB file by selecting path and filename or you press the 'OK' to apply your labeling to the previously selected electrodes. Notice, that for auto labeling the number of labeled electrodes from the template file must match the number of electrodes to be auto labeled.



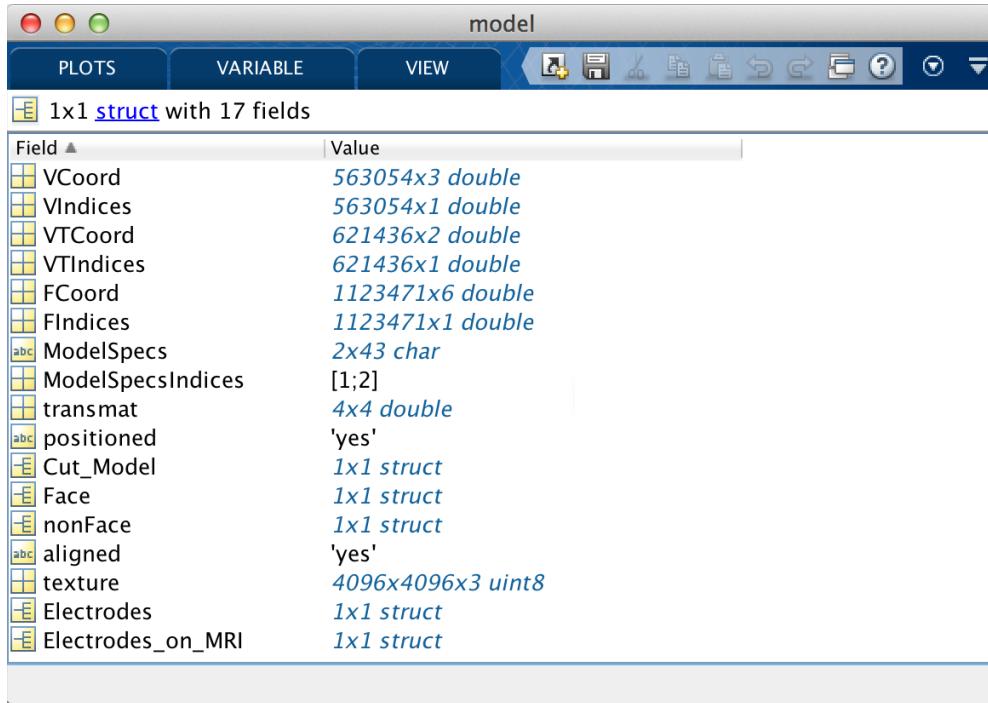
- plotting electrodes on model and MRI

By pressing the ‚show electrodes‘ button, you will get the actual electrode positions plotted on your 3D model and on the MRIs model. If you attached any texture file to your 3D model, the models mesh will be shown in textured fashion. All electrode positions are labeled for you to check them. You now will be able to directly export the electrode positions you got displayed to a MATLAB file on your hard drive. Click the ‚export‘ button and the saving dialog emerges. By pressing ‚OK‘ the current view will be closed.



- **output**

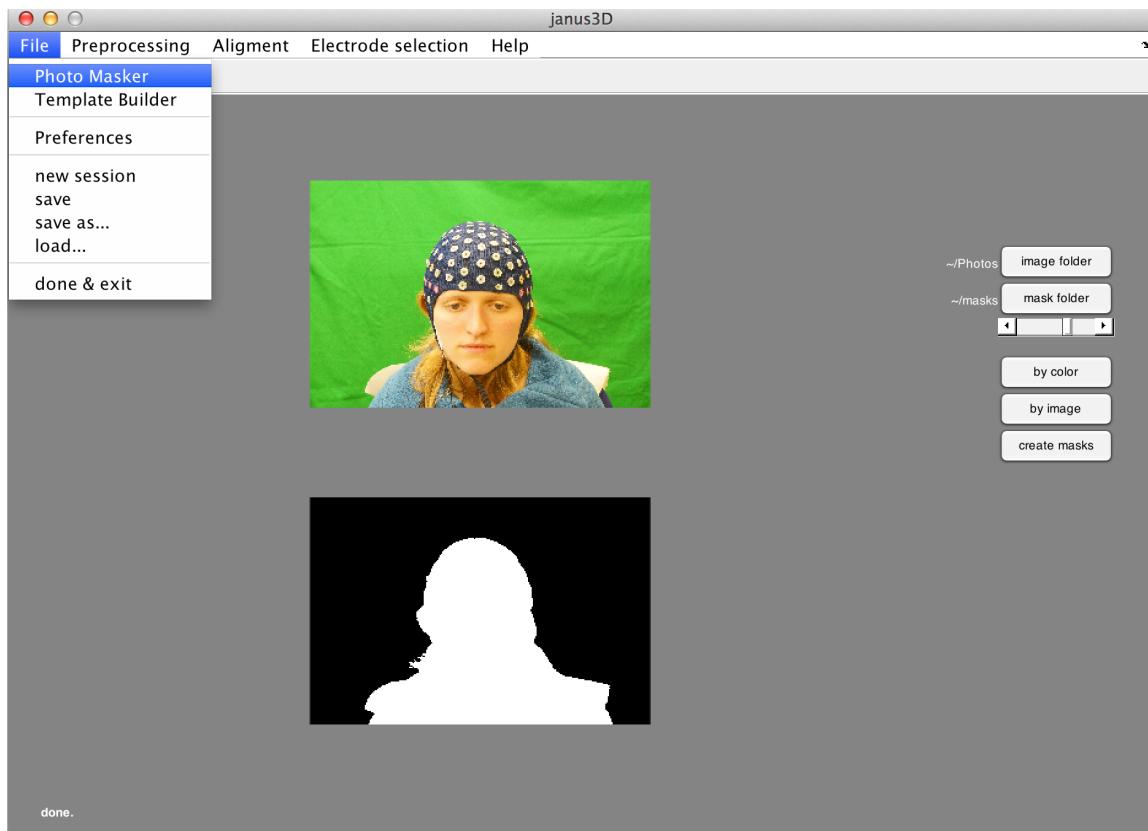
When clicking the ‚done & exit‘ button accessible from ‚File‘, your current processing state will be assigned to the base workspace of MATLAB. It contains a structure that looks like the following one:



VCoord:	Vertex coordinates
VIndices:	Indices of vertex coordinates from the original .obj file
VTCoord:	Texture coordinates
VTIndices:	Indices of texture coordinates from the original .obj file
FCoord:	Column 1,3,5 indices for vertex points building a triangular face Column 2,4,6 related indices for the texture points building a triangular face
FIndices:	Indices of face indices from the original .obj file
ModelSpecs:	Additional information captured from the original .obj file
ModelSpecsIndices:	Indices of additional information captured from the original .obj file
transmat:	Transformation matrix that transforms the original model to the actual state
positioned:	Showing that the model was prepositioned
Cut_Model:	Vertex and face coordinates for the cut model of face selection
Face:	Vertex and face coordinates for the selected face
nonFace:	Vertex and face coordinates for all points except the selected face
aligned:	Showing that the model was aligned to the MRI
texture:	Attached texture file
Electrodes:	Electrodes determined on the model
Electrodes_on_MRI:	Electrodes projected to the MRI's outer surface (scalp)

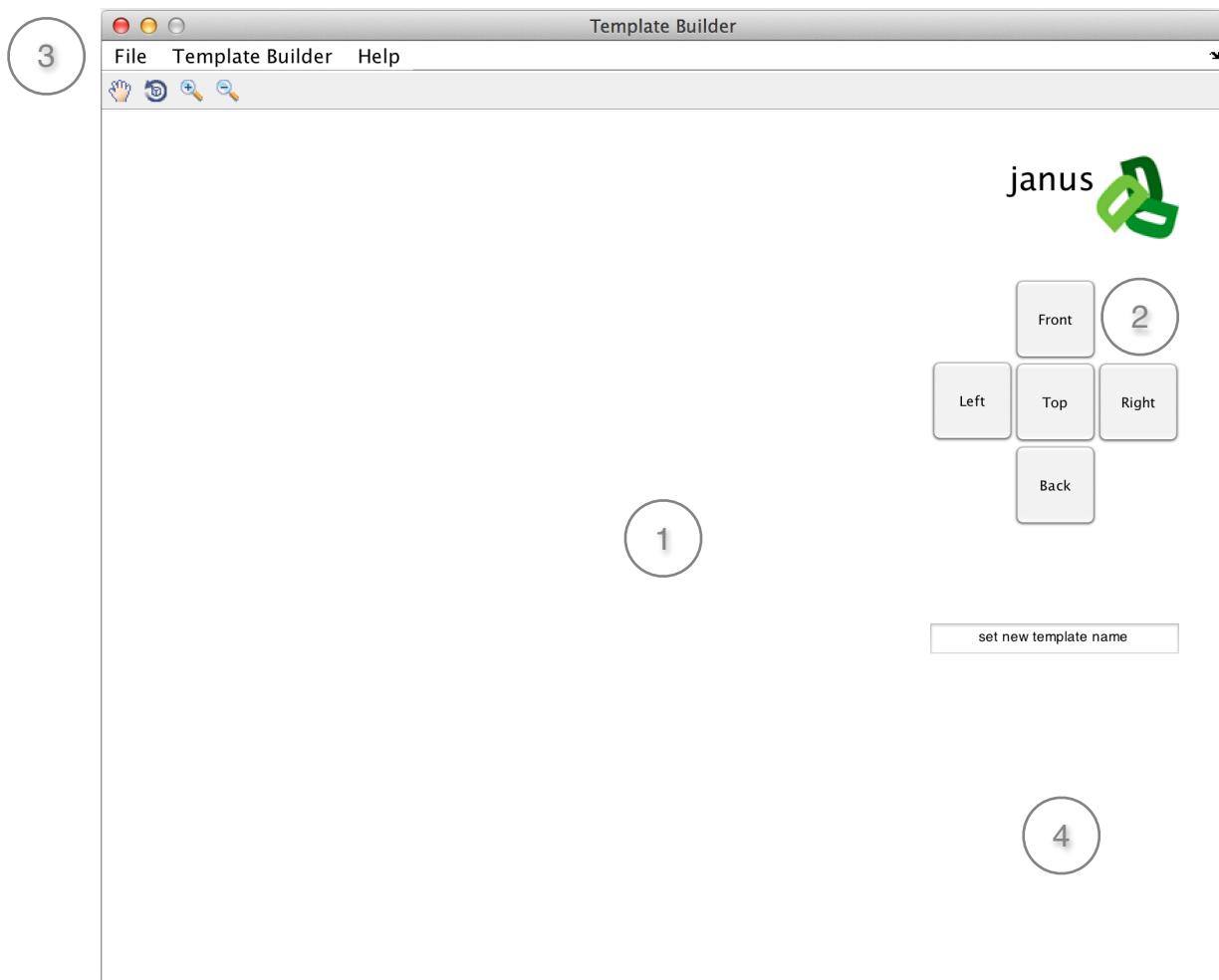
Photo Masker

The Photo Masker is a tool within janus3D to create masks of pictures either taken in front of a greenscreen or with a static background. Open janus3D and select File -> Photo Masker. Select the folder where all images (*.jpg) you want to mask are stored. Afterwards select the folder where the masks should be saved in. Click ,by color‘ to select an even background color and draw a field framing a part of the background and double-click it. Afterwards you can adjust the tolerance of the algorithm using the slider and once you are fine, click ,create masks‘. You also can create masks using a single background image, which should be the same for all images, by clicking ,by image‘. This background image should be exactly the same scenery but without showing the object. The algorithm than subtracts the image from the background and creates the mask. You also can adjust the tolerance using the slider. janus3D will create a mask for each picture and saves it inside the folder selected. The masks are saved in the following way: [original filename]_mask.png. This is necessary, since Photoscan’s default mask selection is based on that naming.



Template Builder

The Template Builder is a tool within janus3D to interactively create templates of EEG electrode caps for automatic labeling. Open janus3D and select File -> ,Template Builder‘. You can change existing template files edit color codes and apply schemes to the template file determining in which order the labels shall be arranged.



1 - operation window

The operation window is the large field in the center of the ,Template Builder‘ window. It will show the currently selected electrodes depending on which view point was selected (2).

2 - view point specification D-pad

Located in the upper right part of the window, you can select the viewpoint, from which the selected electrodes are going to be displayed. Except for ,top' all electrodes are hidden, that you would not see physically.

3 - main functions

At the top side you find all of the main functions that the ,Template Builder' provides. Selecting ,File' lets the Template Builder expand all session relevant features like saving or loading ,Template Builder' sessions. ,Template Builder' includes all relevant steps for preparing the template files.

4 - live preview

When creating a color scheme for your template, it is useful to see a live preview of what you did so far. For this reason a colored rotatable scheme will be displayed in the right lower corner of the window. Clicking next to it will create a larger preview window that allows you to inspect your process more detailed.

Workflow

To create your own template file that fits best to the cap system you use, you first should create one or more labeled electrode files using janus3D. Because the auto labeling function of janus3D uses all sets of electrodes stored in the template file to make a label decision you should consider using 5-10 sets of labeled electrodes to create a template. Using only one would make the auto labeling inaccurate and using too many, would make it too slow, so 5-10 will work as a good compromise.

Importing electrode files to be used as part of the template is fairly easy. Just click ,Template Builder' -> ,import electrodes files...' and a window will show up asking you to select the electrode files you want to include. You can select multiple files if you want to. Afterwards the first of the selected files will be displayed in the operation window, including previous electrode labels. The color will be gray for all electrodes, by default.

You can select the preferred view point by clicking a button of the D-pad. You also should type a name for the created template file into the editable text box asking ,set new template name'. This is NOT the filename, but the name that will be displayed inside the preferences, when you selected the relevant template file.

Now it is your turn to think of a useful color scheme that makes it easy for you to recognize labeling errors during the auto labeling process. For some EEG cap systems stripes might be a good

solution, but for others you might prefer colored fields. To select a color, click the white space between the electrodes and recognize your cursor's change. Draw an outline for all electrodes you want to select and double-click the selected field. A color selection window will appear, asking you to select your color of choice. After selecting the color the electrodes you selected will disappear from the operation window, to make it easier for you to select further electrodes. Once you are done, click ,Template Builder' -> ,build template...' to build your template file. Select a place where you want to store it. Now you can select your own template file from the ,Preferences' window of janus3D to be your template file used for auto labeling and guided manual electrode selection.

The ,Template Builder' also provides a function to load a color scheme to apply it to a set of electrodes. For example if you have small and medium electrode caps that are similar, but only different in size, you might want to create separate template files for both, but once you created one, you can import the color scheme also to the second by clicking ,Template Builder' -> ,import color scheme...'.

A second problem that might occur is, that you might want to sort the labels in a specific way. This can be done by clicking ,Template Builder' -> ,import label sorting scheme....'. All your electrode labels will be sorted according the labels you imported via .txt or .mat file. The file that serves as the template, must contain all the labels in the same spelling and one label per line.

