Accurately recorded head fiducials and electrode positions are essential for moving toward high-resolution EEG functional source imaging!

get_chanlocs

3-D localize scalp electrodes from a 3-D head surface image!

Don't ask subjects to wait through tedious 1-by-1 electrode position digitizing.

Use *get_chanlocs:* An EEGLAB plug-in (using functions in FieldTrip)

Record the 3-D positions of scalp electrodes relative to fiducial head points
from a 3-D head image recorded quickly using a 3-D imaging device
e.g., the Structure Sensor Camera (*http://structure.io*)

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History

EEGLAB plug-in *get_chanlocs* implements [functions created for FieldTrip](#).

Read [Homölle, S., & Oostenveld, R. (2019)](#) for more details.

EEGLAB plug-in ***get_chanlocs*** v1.0

by Clement Lee and Scott Makeig, SCCN/UCSD, beginning 12/17.

Currently implemented to use head models from a Structure Sensor camera (http://structure.io) for MATLAB R2016b.

Note: Any *.obj* file containing a 3-D head image may potentially be usable.

Support files use extensions *.mtl* (material texture library) and *.jpg* (JPEG) to fill in 3-D model colors and textures.

→*We welcome news of use of get_chanlocs with other scanners*.

get_chanlocs – process overview

1. Capture a 3-D (*.obj*) head image (e.g., using a Structure Sensor camera attached to a tablet).

2. Save the 3-D image with the EEG data for *later* analysis .... Then, when analysis begins, ...

3. From the EEGLAB menu running on Matlab, load EEG data and call ***get_chanlocs*** to read the 3-D head image.

4. [optionally] Anonymize the face by changing all skin-tone pixels to grey.

5. Align the 3-D image to CTF (mm) coordinate system by locating 3 fiducial points on the head image

    (**NAS** = nasion; **LHJ** = left helix/tragus junction; **RHJ** = right helix/tragus junction).

5. Click on the position of each scalp electrode on the 3-D head image.

6. [optionally] Shrink the electrode locations inwards to the scalp to compensate for electrode socket height.

7. Verify automatic channel label assignment.

8. Write channel labels and locations to a *.txt* file.

9. Import the *.txt* file labels and coordinates into the *EEG.chanlocs* structure.

10. [optionally] Delete the *.txt* file.

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Ethical Considerations

- An ethics review body will likely consider head images as personally identifiable information

- Obtain consent so that images may be acquired and stored or shared!

- Here is a link to the example consent form shown on the right

EEG HEAD IMAGE RELEASE CONSENT FORM

As part of this project, we will record a 360-degree image of your head including the electrode cap so we can later record the exact position of the electrodes with respect to your brain and head features. Please initial below to indicate the uses of these images to which you are willing to consent. You have the option of consent to allowing us to use the full image of your head, or to use a version in which the face will be greyed out. This is completely voluntary and up to you. In any use of the image, your name will not be identified.

You agree this 360-degree head image can be: Anonymized   Full

1. Studied by the research team for use in the research project   _____   _____

2. Shown to subjects in other experiments   _____   _____

3. Used for scientific publications   _____   _____

4. Shared for use by other researchers   _____   _____

5. Shown at meetings of scientists interested in the study of the
   cognitive sciences, biology, and signal processing   _____   _____

6. Shown in classrooms to students   _____   _____

7. Shown in public presentations to non-scientific groups   _____   _____

8. Used on television and radio   _____   _____

You have the right to request that the 360-degree head image be erased at any time.

You have read the above description and give your consent for use of this 3D image as indicated above.

_____   _____   _____   _____
Signature   Date   Witness   Date

I. Choose a scanning app

- We have tested two different scanning apps:

    - One app, **Scanner**, comes with the Structure scanner itself (*structure.io*).

    - The other, **itSeez3D,** is produced by another company (*itSeez3D.com*).

    - In our testing, the **itSeez3D** app produces more consistently good images with less dependence on ambient lighting, etc. We have worked with the company to find optimal head model parameters to use with ***get_chanlocs***.

    - Commercial use pricing for **itSeez3D** is high – but they are offering low cost educational research licenses (inquire after creating an account).

Capture the head image using the **itSeez3D** app

- An alternative 3-D head image acquisition app: the official **itSeez3D** webpage

- An itSeez3D scanning demonstration video is available here.

- Educational research licenses are available.
  - Inquire by email at support@itseez3d.com after you create an account.

- In our experience the **itSeez3D** app uses a more refined user interface and produces smoother scans than the **Scanner** app.

- First check the newly scanned head model using Low-Res preview mode.

- Cloud-based processing can then return a Hi-Res model
  - → Ask for the head model to be processed with **400k uniform polygons.**

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Sample hi-res **itSeez3D** head model
(BioSemi Cap)

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Sample hi-res **itSeez3D** head model
(EGI Geodesic net)

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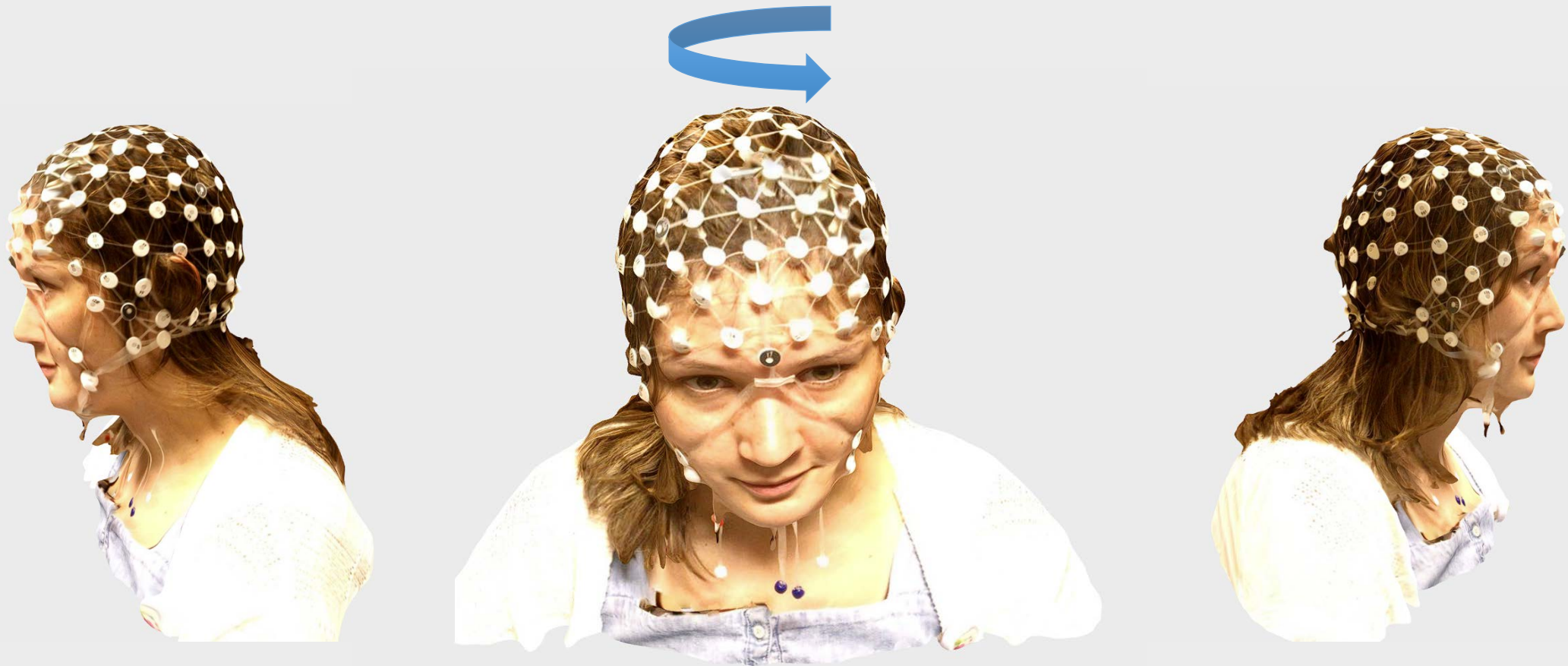
Else, capture the head image using the **Scanner** app

- [Official guidance for using Structure company's Scanner app](#)
  - Stand about 1 meter (or 3 feet) away from the object or the person.
  - Make sure that you have an unimpeded 360° path around the object or person so you can capture an entire scan easily.
  - The Structure Sensor works best indoors or outside of direct sunlight.
- After the scan is complete, select 'Color View' tab on the Scanner app.
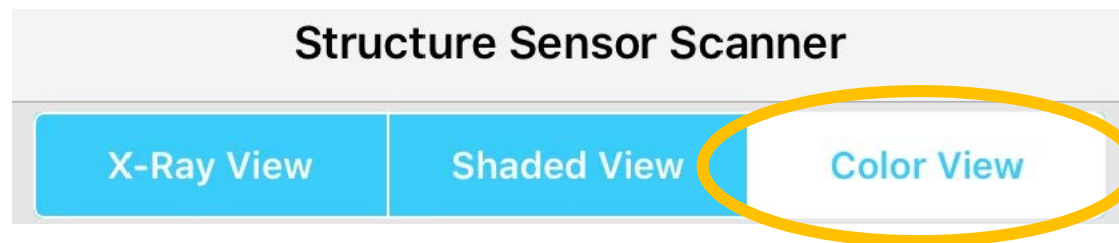
- Finish processing the Color View before emailing the file!
  - Otherwise, the *.zip* file will only contain the *.obj* but not the *.mtl* and *.jpg* files.

Sample **Scanner** app head images
(with optional *get_chanlocs* face greyed out)

Good enough model – Keep it!

Not so good – Rescan!
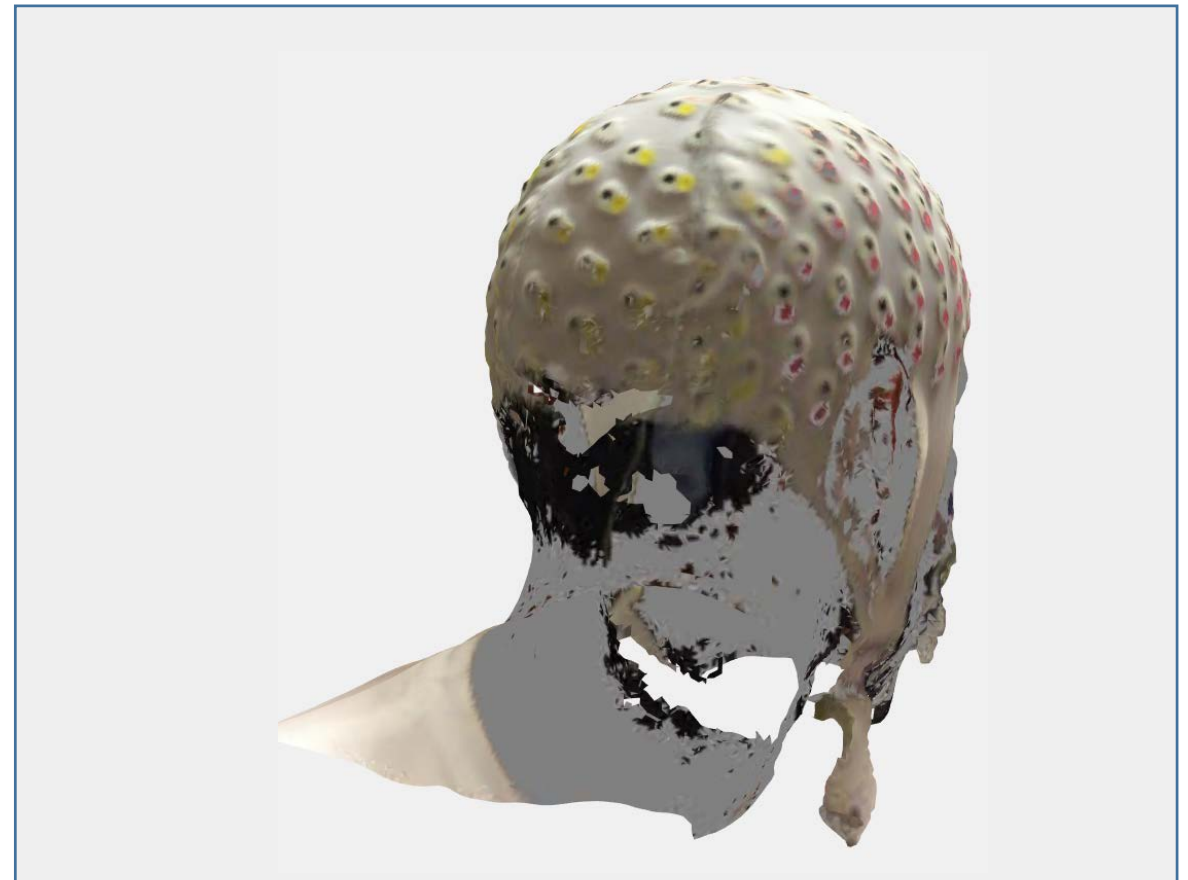
Tips for scanning with either app …

- It best to scan with cap in place but with electrodes not yet (or not still) affixed.
    - If electrodes need to be in place, take care that their wires do not occlude the image of the other electrode sites.
- Use red sticker dots to mark the three fiducial points before scanning.
    - We recommend using red 0.25" dots from any office supply source. ●
- To improve tracking, include the shoulders in the image (not only the head).
- Soften any direct light sources shining on the subject's head (to make luminance more uniform).
- Walk around the subject only once to avoid imaging artifacts.
    - *NB: Instead of panning the scanner back and forth to fill in missing areas, restart the scan!*
- After scanning, check the scan quality → Redo the scan if needed
    - Are the three fiducial points (red dots) visible?
    - Are there any holes in model head image (e.g., holes behind ears, at back of head, etc.)?
    - Are the imaged electrodes blurry from subject movement or overlapping scan artifact?
    - Are the back and sides of the model too dark, or is the top too bright to accurately mark the electrode centers?

Salvage mode
for models with glitched or missing textures
### (with optional *get_chanlocs* input 'grayTextures')

- Ideally, model previews should be carefully inspected and bad scans should be redone.
  - If a bad scan mistakenly passes inspection, it may still be possible to extract channel locations.

- Example below: Here poor scanning lead to poor texture warping (left), but implementing gray textures (right) shows an underlying mesh with pronounced bumps, which should yield reasonable electrode locations (note in the greyed image – only one nose!)
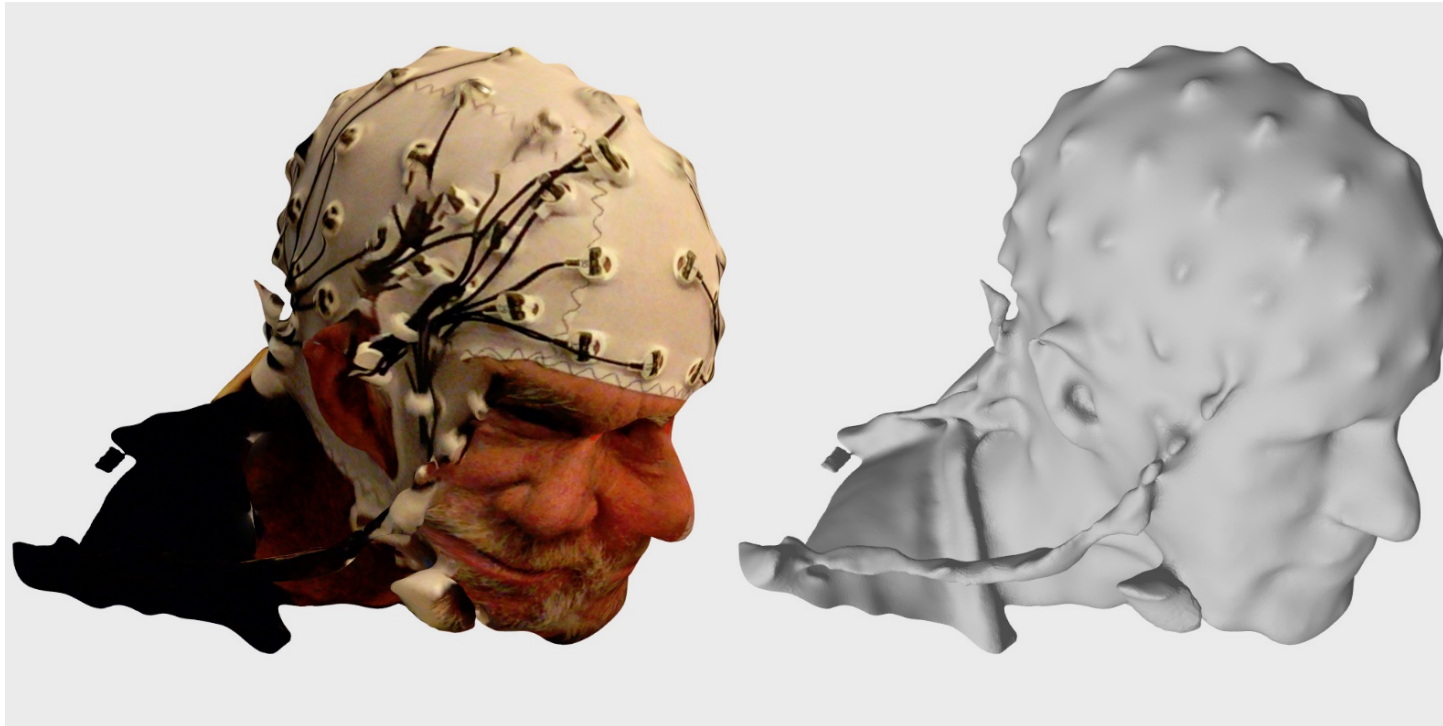
Then, any time after the recording session, to begin data analysis first read in the data and channel labels, then compute and store the 3-D electrode locations …
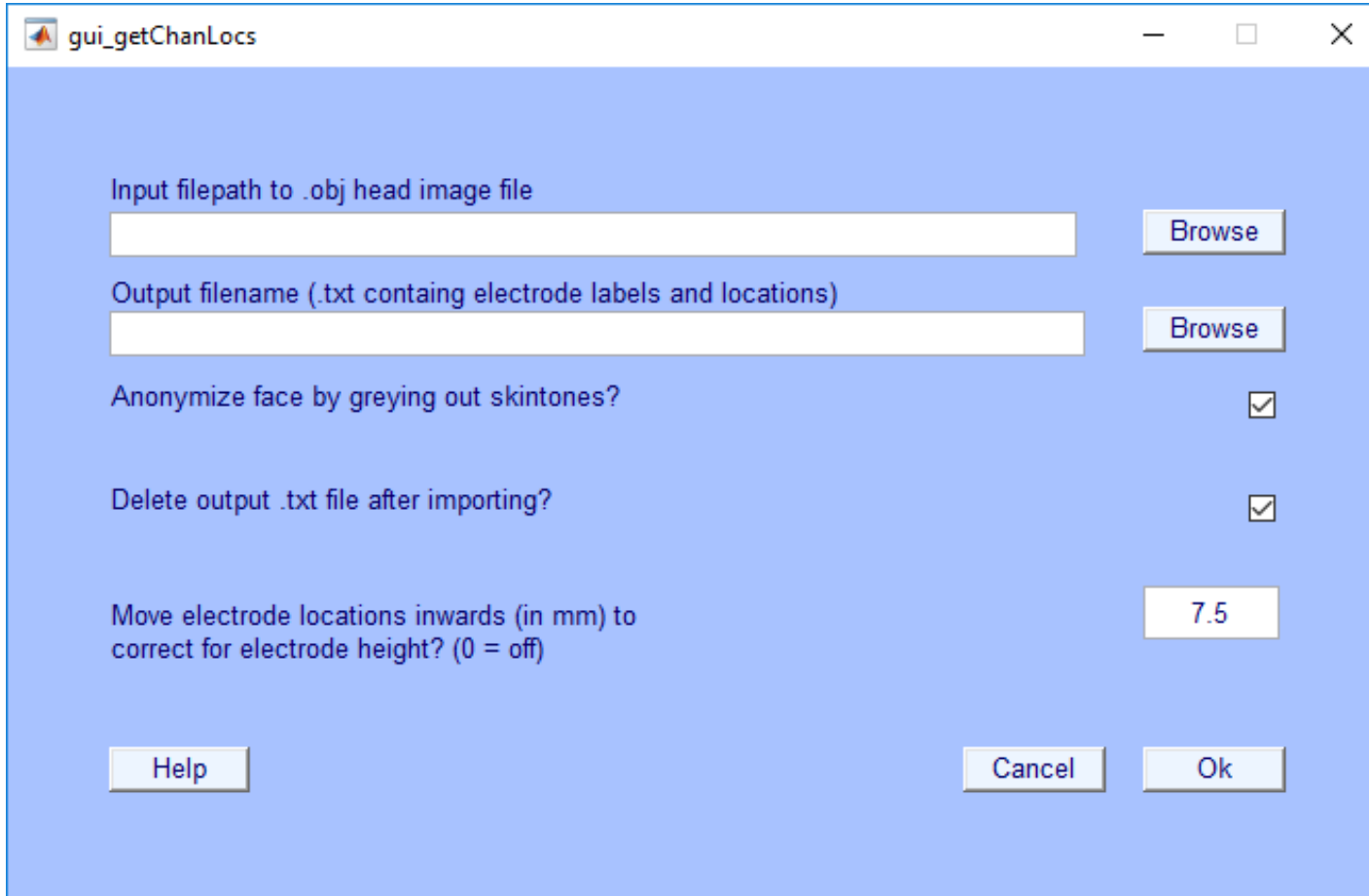
II. Call *get_chanlocs* from the EEGLAB menu
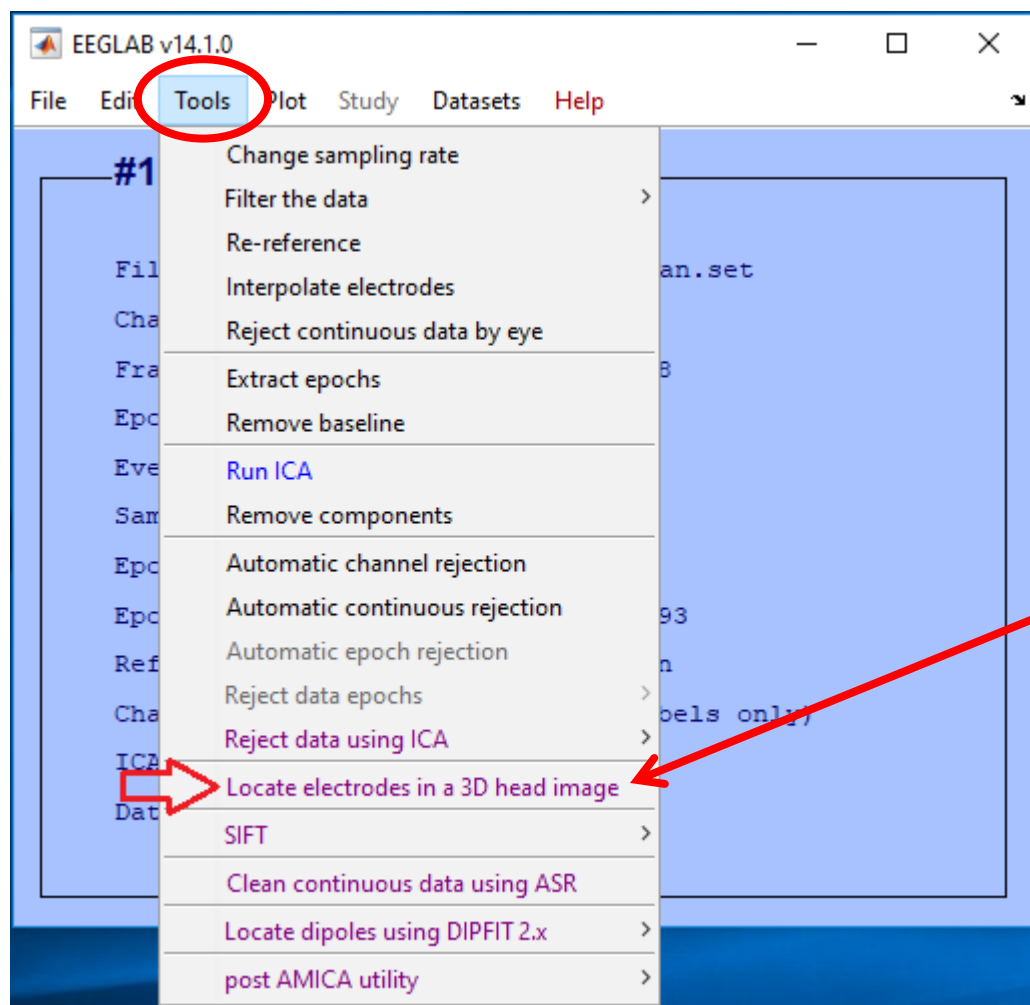
- Requires an already loaded EEGLAB dataset with channel labels (any labeling system):
  - *EEG.chanlocs.labels* are used to guide the electrode localization process.
  - When *get_chanlocs* finishes, the *EEG.chanlocs* fields are populated (*X, Y, Z*) .
- To begin, select "*Locate electrodes in a 3D head image*" under the EEGLAB '*Tools*' menu.
- Advanced users may call *get_chanlocs* directly via the command line to access optional inputs

The *get_chanlocs* pop-up launch window

- Enter the head image folder.

- Defaults to the entered head image folder.

- Cap-specific electrode height adjustment (GUI default: 7.5mm for EasyCap/Biosemi).

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Sample *get_chanlocs* launch window

- Enter the head image file folder path (containing the *.obj, .mtl,* and *.jpg* files).
- Name a *.txt* output file path.
- Press "Ok" to advance.

Locate three fiducial points on the head image

- The 3-D head image pops up in a new window.

- Follow instructions in the command line output.

- The figure supertitle indicates which fiducial to select.
  - **NAS – nasion**
  - **LHJ – left helix/tragus junction**
  - **RHJ – right helix/tragus junction**

Command line output: Beginning fiducial localization

```
Select (in order) Nasion, Left Helix/Tragus Junction,
and Right Helix/Tragus Junction...
Use the mouse to click on the indicated scalp positions
Press "r" to remove the last point added
Press "+/-" to zoom in/out
Press "w/a/s/d" to rotate
Press "q" to quit and advance when done
```
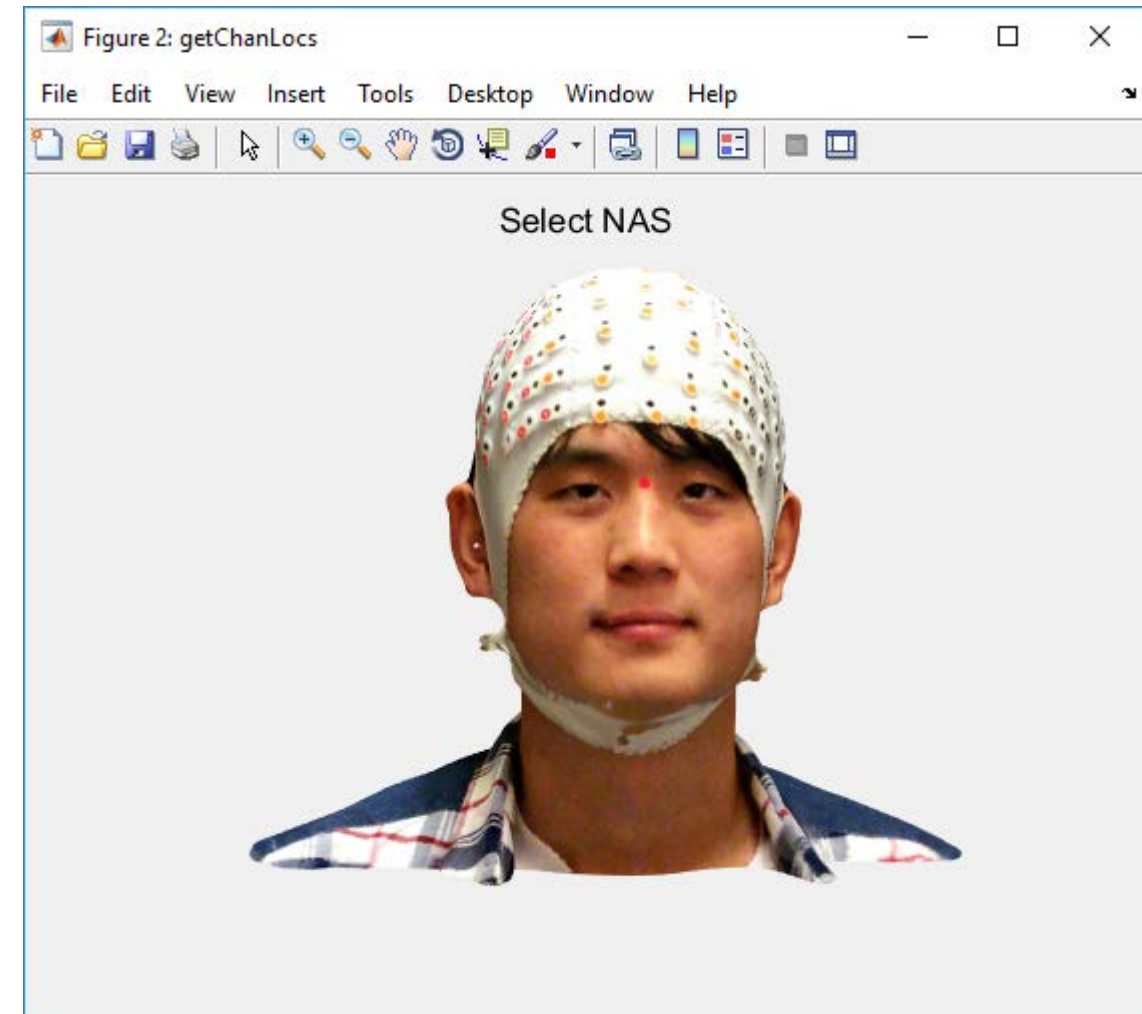
Fiducial point definitions

Nose Fiducial (NAS)

Ear Fiducials (RHJ,LHJ)

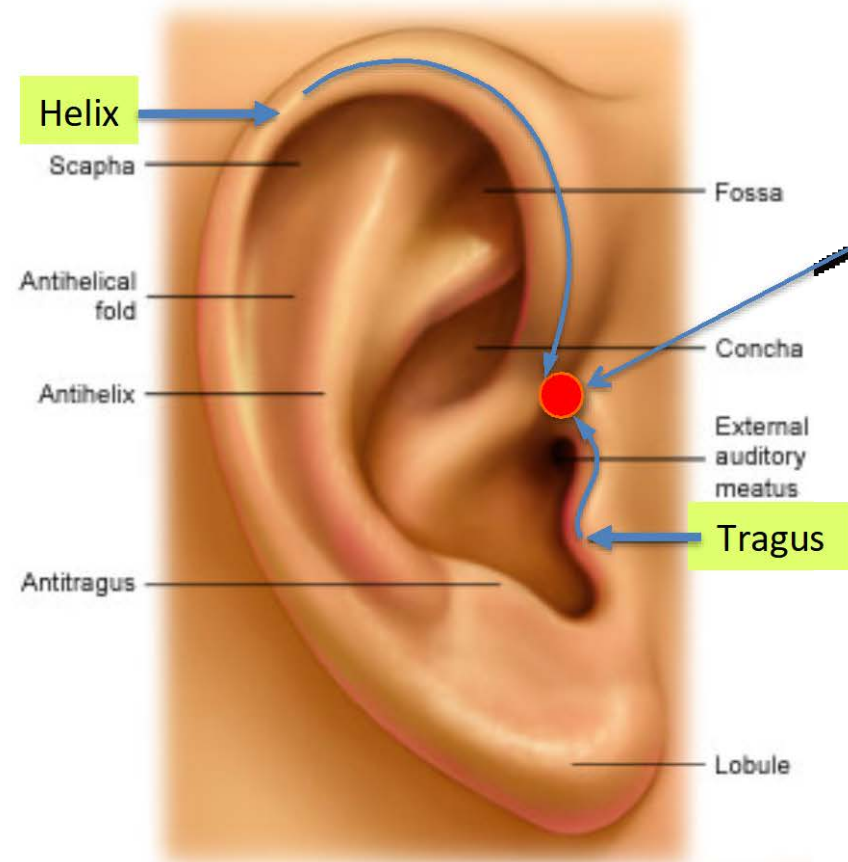**Nasion**
at the lowest point between the nose and forehead

(top of nasal bone at the nasofrontal suture)

GetChanLocs

Helix

Scapha

Antihelical fold

Antihelix

Antitragus

Fossa

Concha

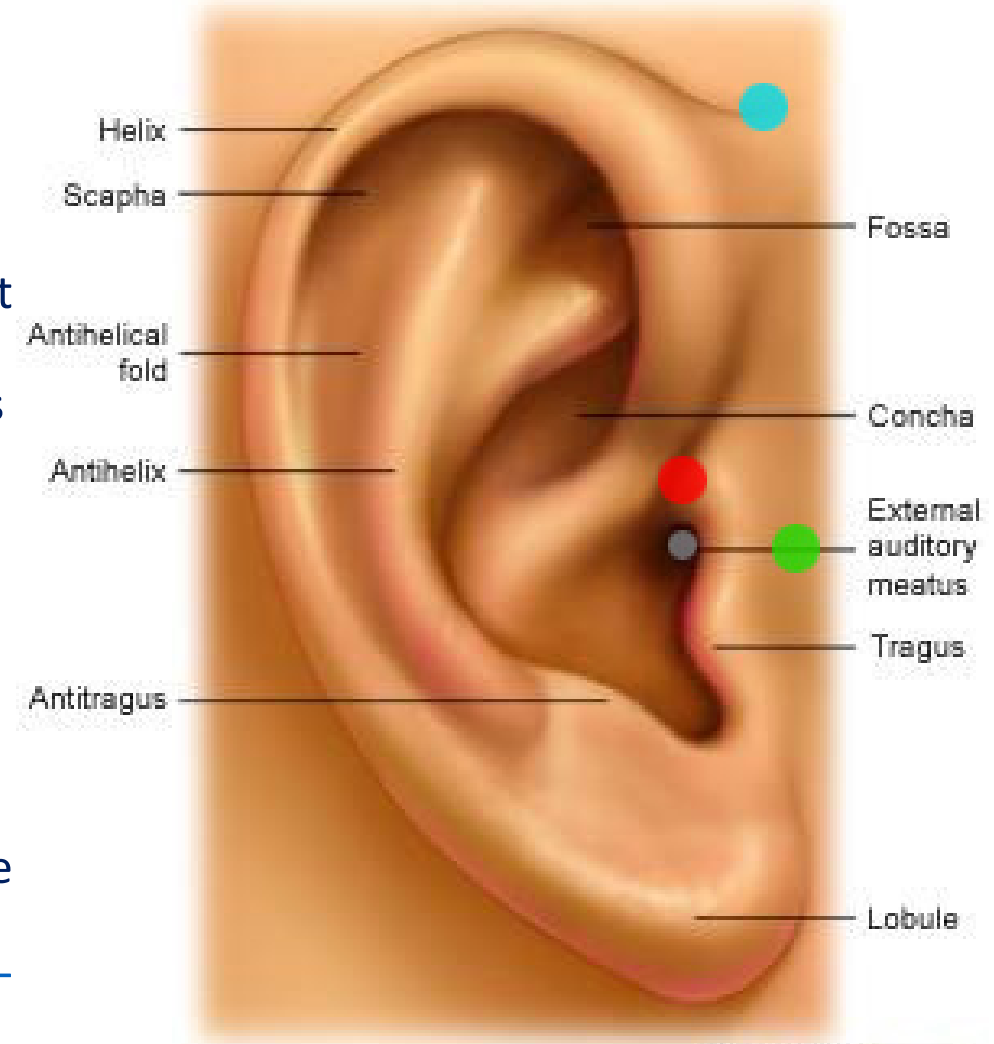External auditory meatus

Lobule
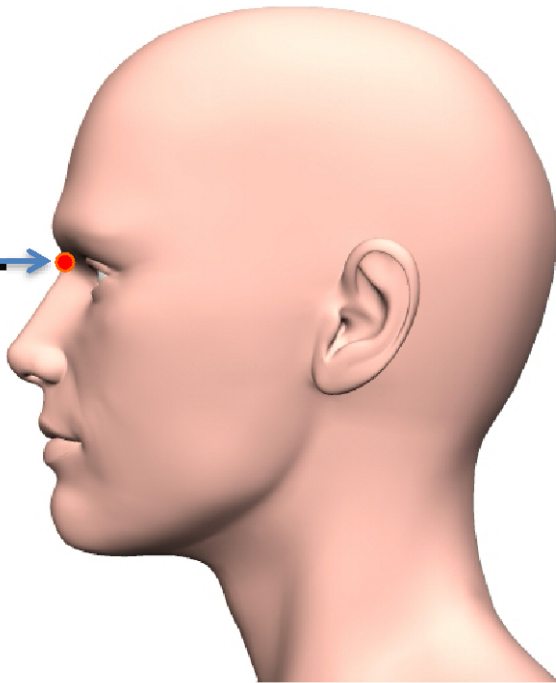
R. Helix/Tragus

at the intersection of the Helix and Tragus at the edge of skull opening (external meatus).

Tragus

GetChanLocs

How to define the lateral fiducials?

- Consistency is key when using fiducials; collaborative or data mining projects become impossible without accurate position labels.

- Traditionally in EEG, the terms Left/Right PreAuricular (LPA/RPA) are used to refer to the ear fiducials.

- While LPA/RPA are palpable anatomical features, they are difficult to locate in anatomical MR head images.

- To address this issue and allow for MR coregistration, various labs utilize in-house fiducials (unfortunately, some do so while retaining the LPA/RPA label).

- We suggest using the terms: Left|Right Helix-Tragus Junction (LHJ|RHJ), Left|Right Ear canal (LEC|REC), Left|Right Helix-Scalp Junction (LHS|RHS), and Left|Right PreAuricular (LPA|RPA).

- We strongly recommend the use of the Left|Right Helix-Tragus Junction (LHJ|RHJ) as the *get_chanlocs* lateral fiducials, as these are best defined in *both* 3D and MR head images.

- For a detailed discussion on ear fiducials from the Donders Centre in Nijmegen, please visit: http://www.fieldtriptoolbox.org/faq/how_are_the_lpa_and_rpa_points_defined/
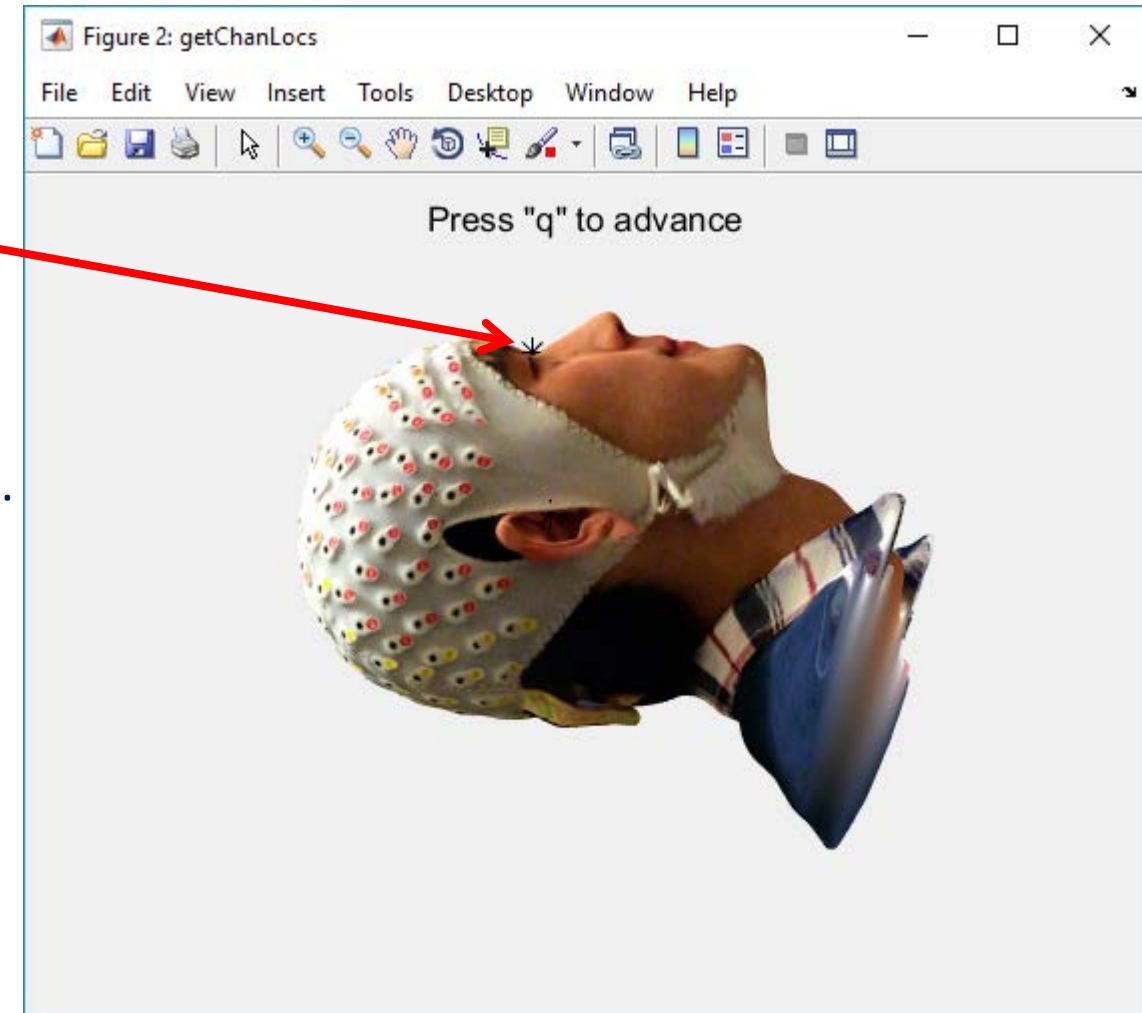

Helix
Scapha
Fossa
Antihelical fold
Concha
Antihelix
External auditory meatus
Tragus
Antitragus
Lobule

Locate the fiducial points on the head image

- Click on the requested fiducial point to mark it.

  ('✳' will appear)

- The command line details the points selected.

- When all 3 fiducial positions have been selected...

- ... press '*q*' to quit and finalize the fiducial coordinates.

Command line output: Completing fiducial localization

```
Selected NAS at [ -12.1398   -45.0060    99.8503] (1/3) fiducials
Selected LHJ at [ -80.8844    -5.2010     1.1511] (2/3) fiducials
Selected RHJ at [  77.8386    -4.5376     8.8525] (3/3) fiducials
All head fiducials now have locations.
Press "q" to quit and advance or "r" to remove last added point.
```


Figure 2: getChanLocs

File   Edit   View   Insert   Tools   Desktop   Window   Help

Press "q" to advance

Next, locate the fiducial points on the head image again!

- Fiducial locations dictate the axes of the electrode location coordinate system; as such, error propagation from poor fiducial selection is non-trivial.

- *get_chanlocs* requires users to select sets of three fiducials multiple times (at least twice), until the distances between wo most recent iterations are < 2 mm for each of the 3 fiducials.
  - After each successive selection, the command line will either output:
    - "Warning: Fiducial distance tolerance (2mm) exceeded. Select fiducials again," or
    - "Fiducial distances within tolerance. Averaging…"
  - Axes are defined using the three points, the mean of the two accepted measurements

- From inter-rater reliability testing, we find that consistently selecting fiducial (and electrode) positions differing < 2 mm is both feasible and reasonable
  - NB: The 2 mm threshold parameter can be relaxed by modifying *placeFiducials.m.* However, this is not recommended. The suggested solution is to improve user skill – and/or possibly monitor resolution or mouse sensitivity.

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Create or select a *montage template* head model

- A montage template is necessary for automatic channel labeling after the selection process
- ***get_chanlocs*** searches for *.mat* files in the parent folder/directory of the current model file.
  - A different path can be specified using optional input parameter "*templatePath*".
- The pop-up dialogue box differs depending on whether 0, 1, or >1 *.mat* files are found in the parent folder.
- If no template for this montage exists and 10-05 standard labels are in use, the MNI template can be used.
- Else select **Create new template** to process and save the current head model for use as a template in the future.
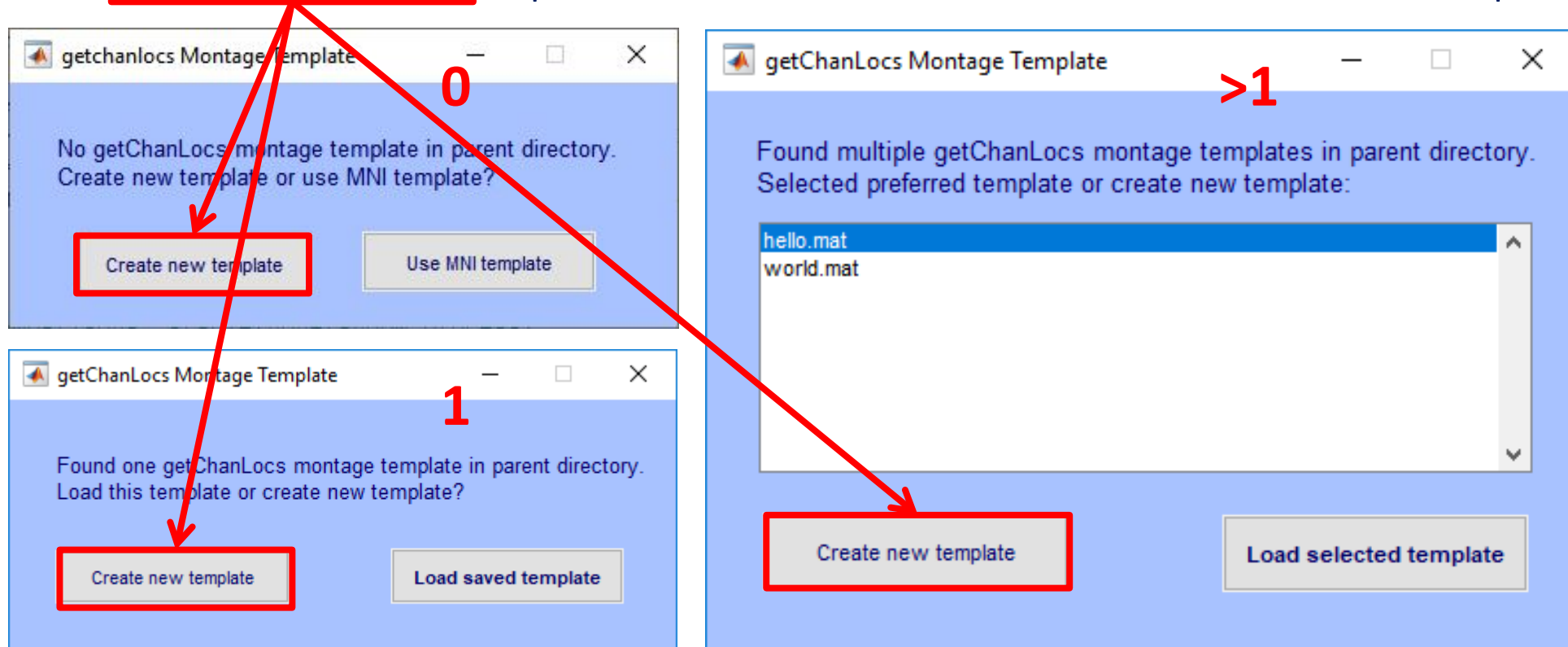
Create a new *template* head model for the montage by locating the requested scalp electrodes on the head model

- Click on each requested electrode (here, 'A12'), thereby marking it with a '✳'
  - Electrodes are requested, by name and in order, based on the EEG recording's channel structure
- The command line will report the location selected.
- Iterate until all montage electrodes are located ...
- Take care – the results will be saved and used as a template to routinely localize electrodes in future sessions using the same montage ...

  → Don't confuse electrode labels / positions here !

- When all electrode locations have been selected ...

  press 'q' to quit and finalize the electrode coordinates.

Command line output: Electrodes selected up to A12 ...

```
Selected A1 at [   95.2789     47.8105     60.8128] (1/128)  channels
Selected A2 at [   78.8512     60.9559     71.1820] (2/128)  channels
Selected A3 at [   87.1619     59.7937     52.7479] (3/128)  channels
Selected A4 at [   62.6215     60.3832     89.6160] (4/128)  channels
Selected A5 at [   59.5454     70.4698     75.7905] (5/128)  channels
Selected A6 at [   68.9906     70.9116     56.9724] (6/128)  channels
Selected A7 at [   74.0183     69.9293     39.6905] (7/128)  channels
Selected A8 at [   45.2540     61.9757     99.2170] (8/128)  channels
Selected A9 at [   41.9856     70.6862     88.4638] (9/128)  channels
```


Figure 2: getChanLocs — Select A12 — A12
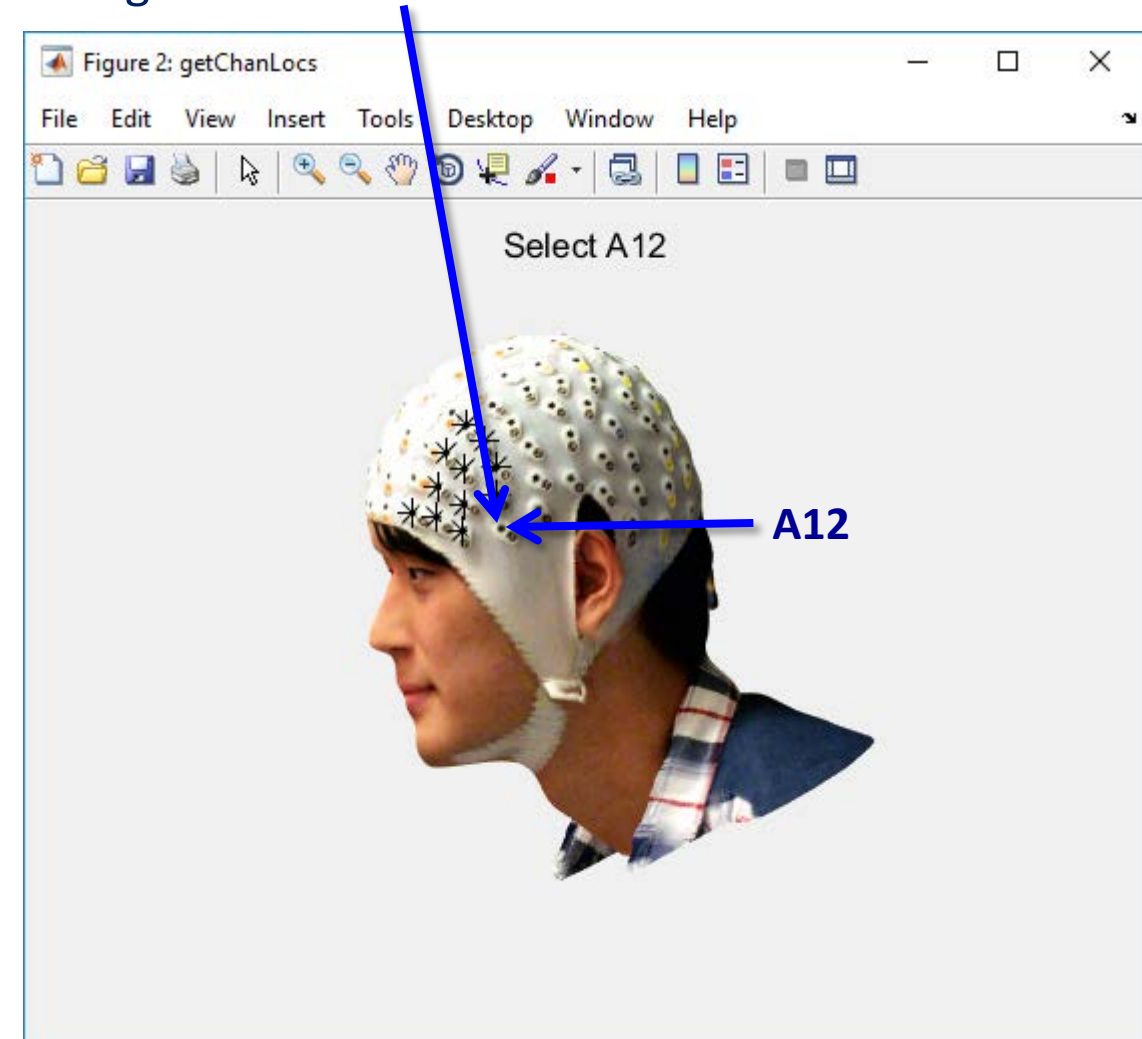
Or load a stored *montage template* head model and localize ('digitize') electrode locations

- Each montage requires its own template. Here, a 64 channel Brain Products actiCAP slim is used instead of the previously shown 128 channel headcap.

- Click on any electrode to mark it with a '✳'

- Select all electrodes before proceeding if possible.

  - Selection order is trivial: electrodes will be automatically rearranged and channel labels automatically assigned.

  - If some electrodes are missed, projected locations will be calculated by warping template to selected locations.

- When all electrode locations have been selected, press '*q*' to quit and proceed to verify automated channel pairing.

Command line output: Point selection report

```
Selected point at [  12.7582  -78.5716   38.1615] (1/63) channels
Selected point at [ -16.5773  -76.1037   49.5314] (2/63) channels
Selected point at [ -28.7362  -73.4537   19.7540] (3/63) channels
Selected point at [ -39.7955  -66.3364   57.9473] (4/63) channels
Selected point at [ -40.7438  -60.4773   82.6377] (5/63) channels
Selected point at [ -60.6500  -52.1931   63.8280] (6/63) channels
Selected point at [ -74.3527  -33.3573   63.9528] (7/63) channels
Selected point at [ -82.6913   -5.7148   64.6265] (8/63) channels
```


Figure 2: getchanlocs

Point selection progress: 8 out of 63

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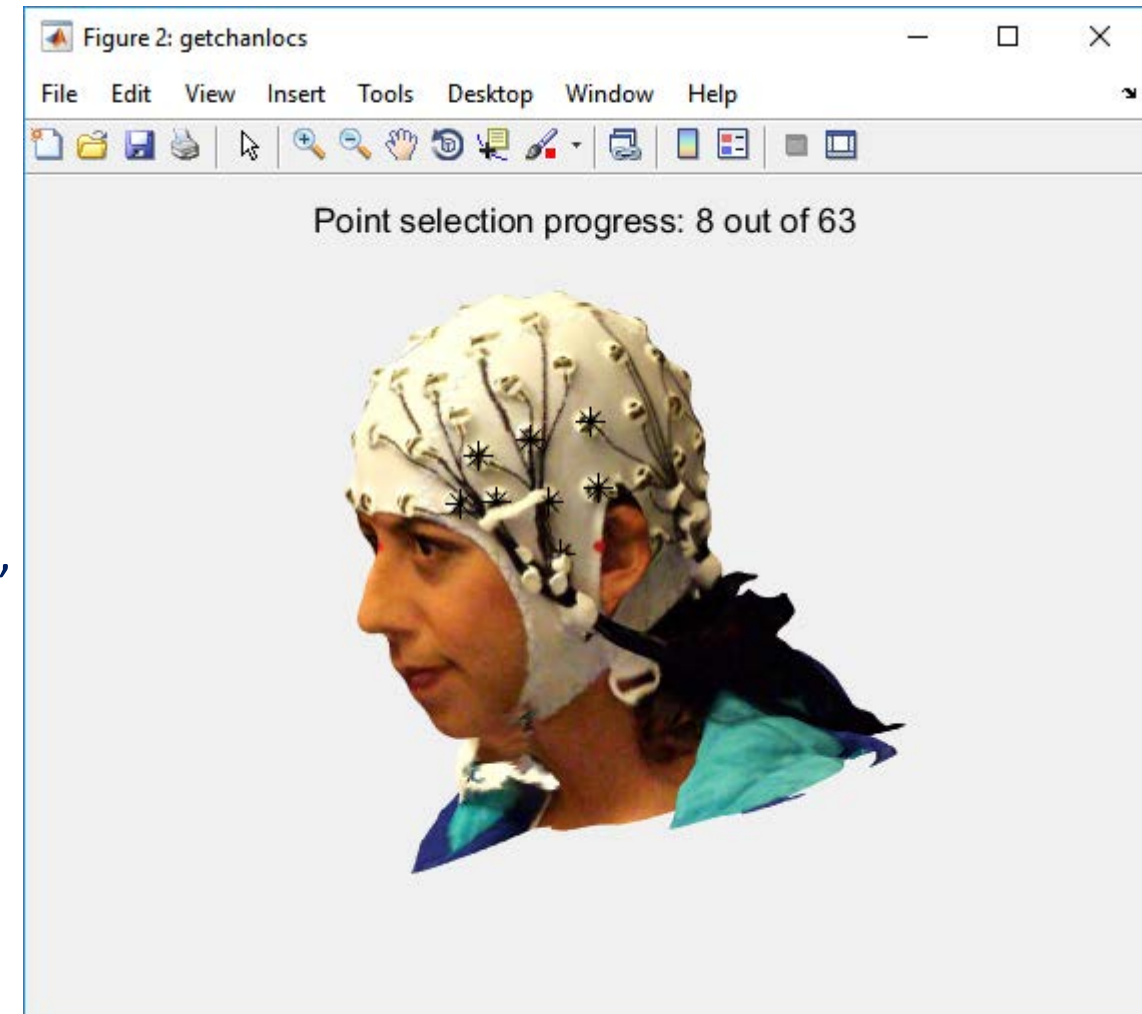
After localizing the electrodes: Verify automatic channel label assignments by comparing to the stored template.

- After you localize the electrodes, *get_chanlocs* automatically pairs each electrode location with the corresponding electrode location on the montage template by Hungarian assignment (minimizing the sum of Euclidean distances between each pairing in the full electrode set).

- Errors may occur, whether from user mistakes during selection process, or algorithm failure (NB: none observed or reported as yet).

- The visual confirmation / fix-up tool is used to address this problem.
  - Montage template electrode locations are plotted as blue circles.
  - Newly selected electrode locations are plotted as black circles.
  - Electrode pair assignments are connected by red lines.
  - Inspect for lines that do not seem to belong in the vector field, as well as for unusually long lines.
  - **If no mistakes are found, press 'q' to quit and proceed.**
  - Pictured (right) is one erroneous pairing (highlighted in yellow for this documentation) from an axial view – Wrong pairs will be relatively far from each other and/or the template & displacement will be in an unlikely direction.

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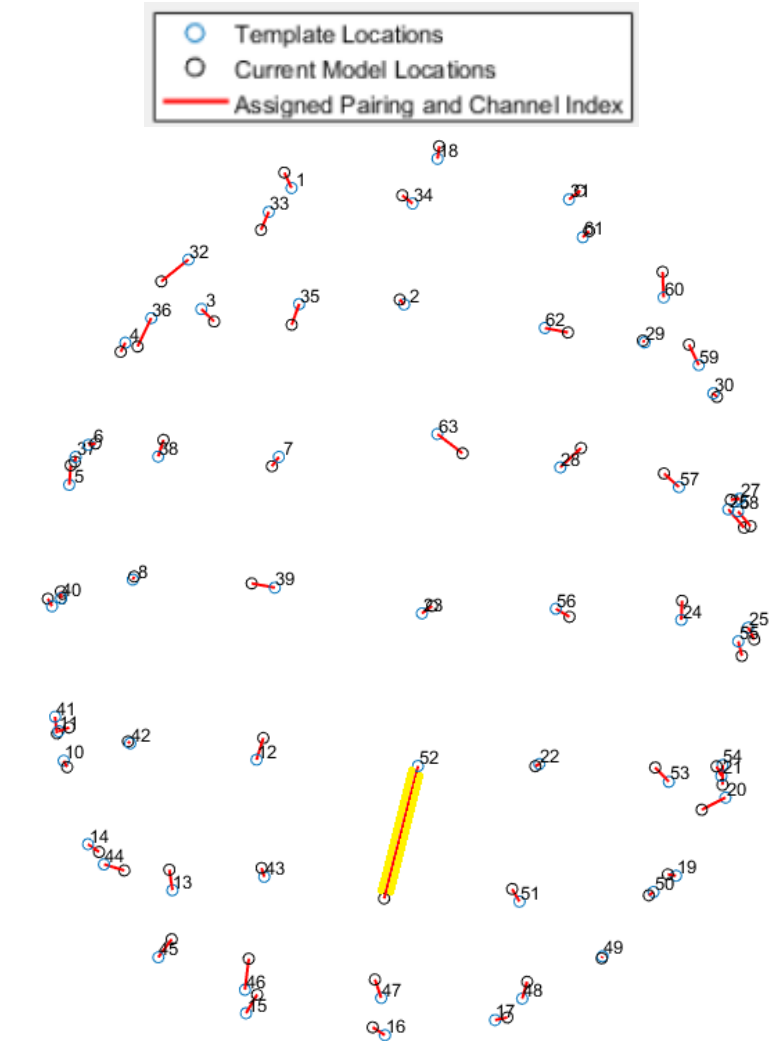
Using the stored montage template: Detect, remove, and reselect erroneous selections or pairings.

- Typically, erroneous pairings occur in clusters but can be traced back to one mistaken location selection.

- In the current example, three pairing errors flowed from one mistake – here, by accident selecting incorrectly the *reference electrode* location instead of the correct channel electrode location.

1. First, press 'r' to **remove** incorrect location(s) from the "Current Model Locations."

2. Next, enter the channel index/indices to remove, based on the numerical annotation(s)
   - In this example, we select one mislabeled channel (index 52).

3. Press 's' to **select** new location pairings (see next slide).

Command line output: interactive fix-up tool navigation

```
Press "r" to remove a selected location
Press "s" to select new location(s)
Press "c" to compute new assignment and show updated plot
Press "q" to quit and advance

Which location(s) should be removed?
Please enter the channel index/indices (e.g. 1 or [1 4 7]): 52
Channel(s) removed! Press "s" to select new location(s)
```
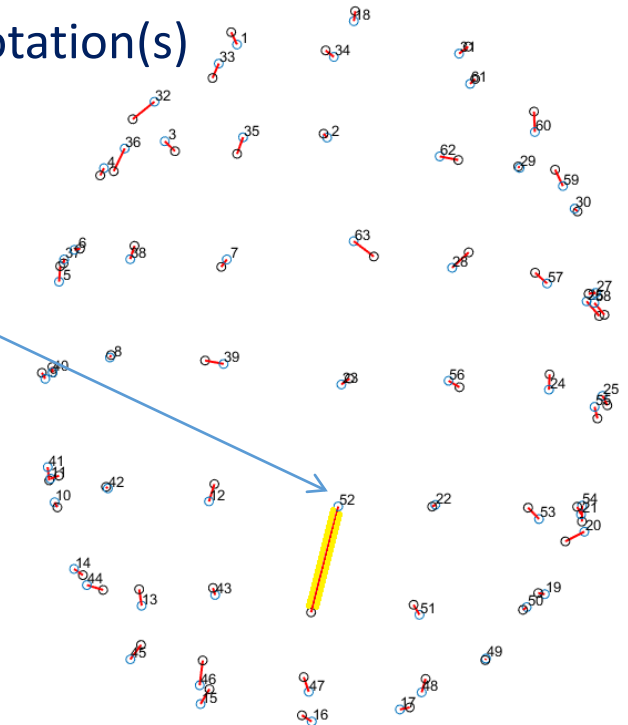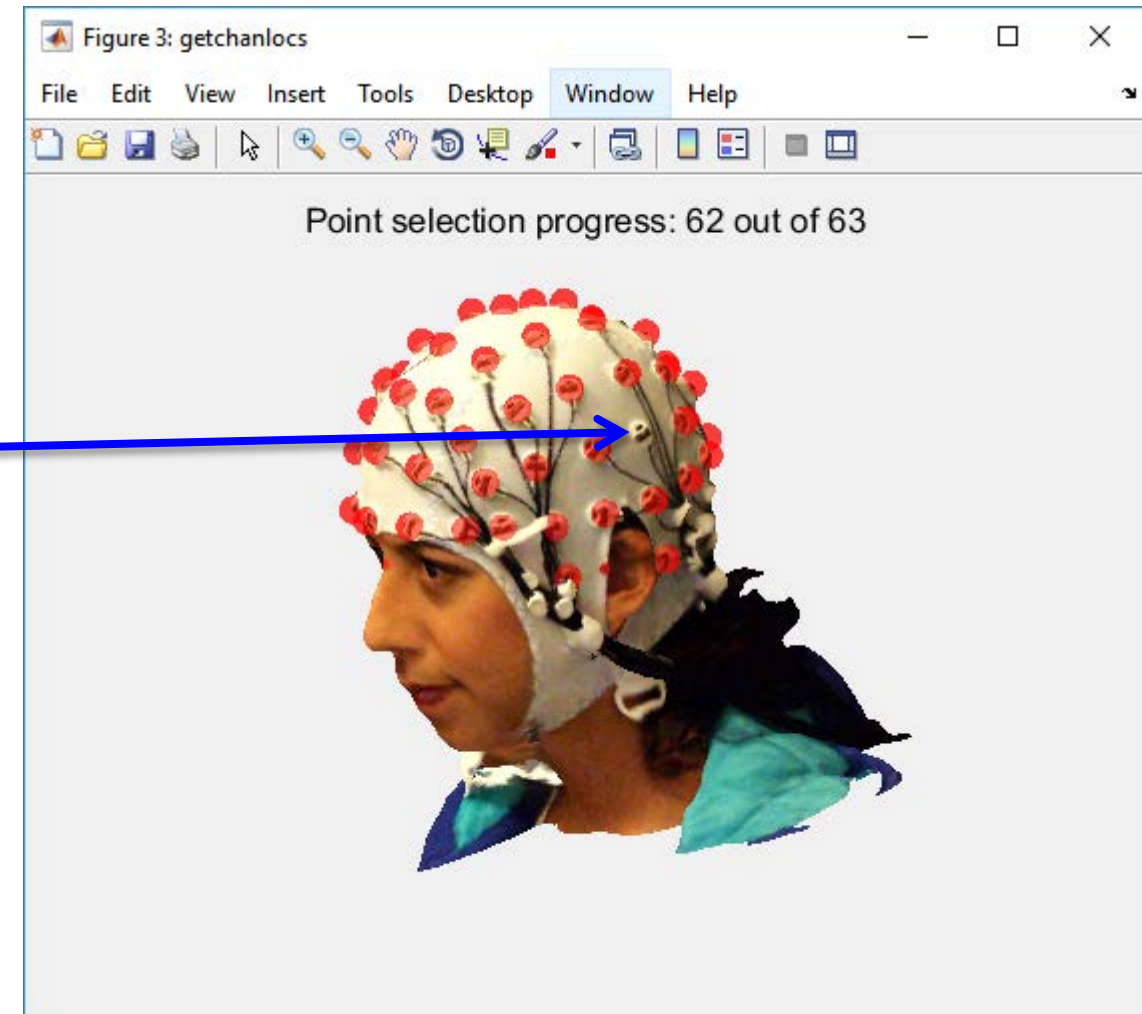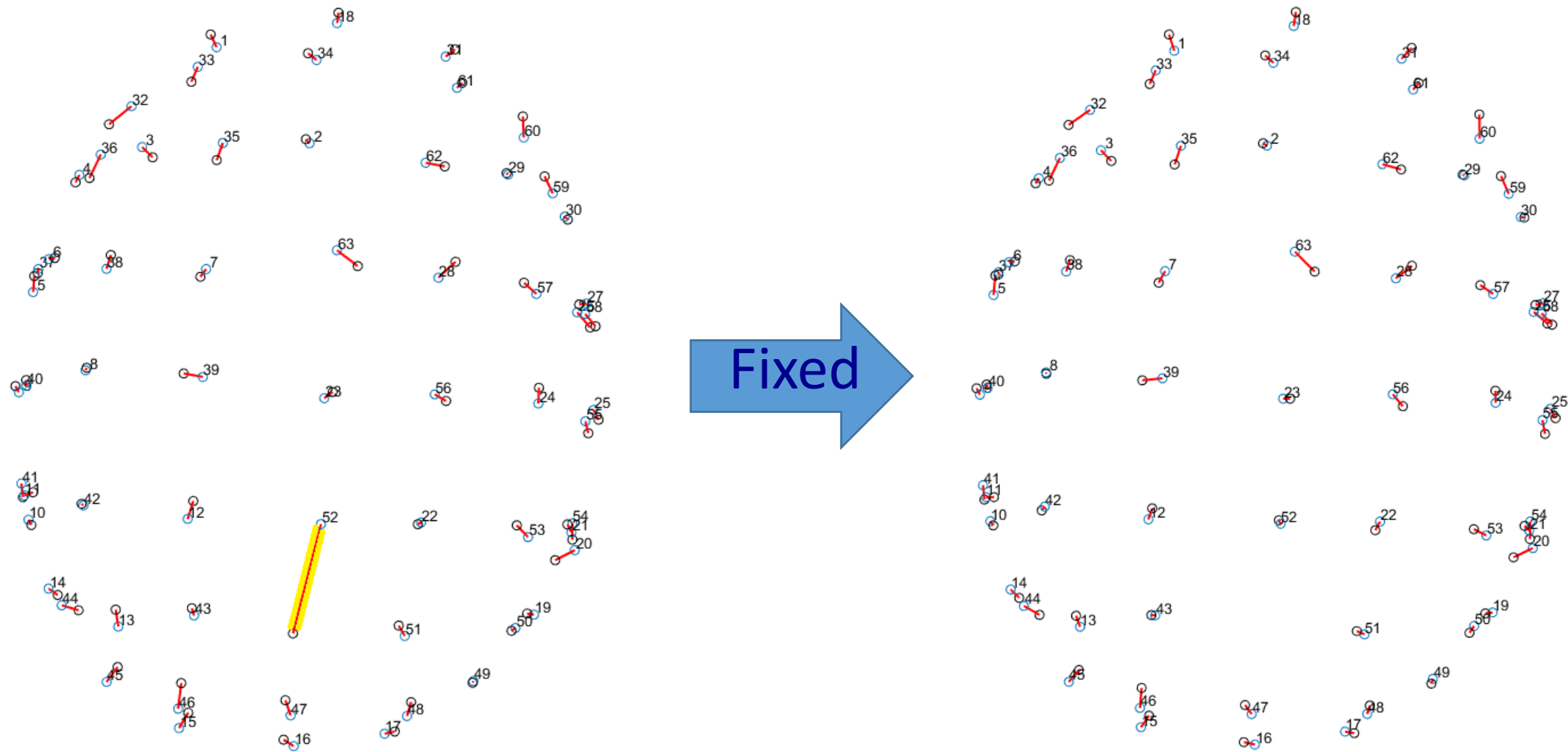
Recovering from errors using the stored montage template: **Select** missing locations and **compute** pair assignments again

- For each suspect location removed from the list, a new location must be selected to take its place.
  - The total number of electrodes required is still the same as the number of electrodes in the montage template!
- After removing location(s) selected in error, press '**s**' to **select** and again locate, any now-missing locations.
  - Previously selected locations are indicated by red spheres.
  - Unmarked electrodes can easily be identified.
  - Click on the electrode(s) to mark with (✳), then '**q**' to **quit**.
  - Then, press '**c**' to **compute** pair assignments again.
  - Updated channel pair assignments will appear (*next slide*).
  - Inspect these pairings again – If OK, press '**q**' to **quit** (else repeat the fix-up procedure using '**r**', '**s**', '**c**', and '**q**'.).

Figure 3: getchanlocs

File   Edit   View   Insert   Tools   Desktop   Window   Help

Point selection progress: 62 out of 63

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Location fix-up

Save the selected locations in the EEG dataset

- When all electrode positions have been specified correctly, *get_chanlocs* then
  - Shrinks the electrode positions radially to the scalp surface by the requested (cap-specific) distance (GUI default, 7.5 mm; command line default, 0 mm).
    - Shrinking subset(s) of electrodes is also supported (for systems utilizing multiple electrode types)
  - Saves a '*chanlocs.txt*' file that records the electrode labels and locations.
  - Imports this *.txt* file and saves its contents in the EEG dataset structure under *EEG.chanlocs*.
  - [optionally] Moves the *chanlocs.txt* file to trash.
  - [optionally] Saves the model and channel locations as a *.mat* file for use as
    the montage template head model.

Command line output: Completing electrode localization

```
Electrode location selection finished.
Moving electrode locations from cap surface in towards scalp by 7.50 mm...
Writing electrode locations to txt file...
Importing locations with readlocs()...
Electrode localization by getChanLocs finished!
```

Accurately recorded head fiducials and electrode positions are essential to progress toward high-resolution EEG functional source imaging!
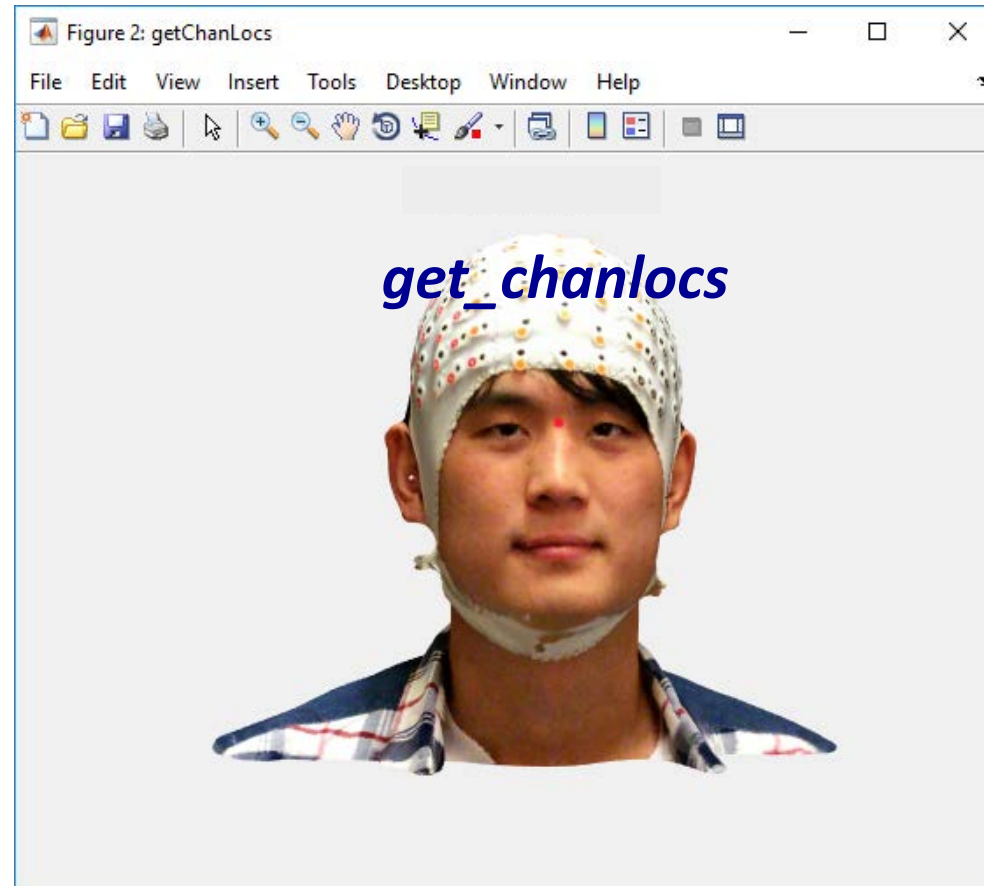
Other EEG tech tools!

BIDS-EEG (psyarxiv.com/63a4y)

HED (HEDtags.org)

NSG (EEGLAB_on_NSG)

ICLabel (iclabel.ucsd.edu)

Open Neuro (OpenNeuro.org)

Questions or suggestions? Please email
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