Reference sheet for *yuki* version 3.0 usage

March 28, 2024

Introduction: The computer program *yuki* is a part of the Automatic Registration Toolbox (ART) package developed by Dr. Babak A. Ardekani. It is designed to automatically segment the corpus callosum (CC) mid-sagittal cross-sectional area from 3D T1-weighted structural MRI of the human brain.

Installation on Linux and MacOS systems: A video demonstration of installing ART software can be found here. Although this video was made for installing *atra*, a different module of ART, the steps are similar.

To install *yuki*, you may need to be logged in as root, depending on the permissions of the directory in which you are installing *yuki*. Let's assume that *yuki* will be installed in /usr/local/art.

(a) Set the ARTHOME environment variable to /usr/local/art. If ARTHOME is already defined on your system, then you can skip this step. Otherwise, "sh" or "bash" users may define ARTHOME using the following command:

export ARTHOME=/usr/local/art

To do this automatically at login, users should add the above line to their ".bashrc" or ".profile" file. Users of "csh" or "tcsh" may use the following command:

setenv ARTHOME /usr/local/art

and add it to their ".cshrc" or ".tcshrc" file.

(b) Download the Linux or MacOS version of the software from https://www.nitrc.org/projects/art. and move it to the ARTHOME directory (e.g. /usr/local/art).

(c) Unpack the package:

cd $ARTHOME

tar -xvzf yuki3.0*.tar.gz

(d) Add the directory $ARTHOME/bin to your PATH. This can be done by executing the following command and adding it to the ".bashrc" file:

export PATH=$ARTHOME/bin:$PATH

Usage:

yuki [optional arguments] -i <input volume>.nii

Required argumen:

-i <input-filename>.nii	3D T1-weighted MRI brain volume in NIFTI format of type short or unsigned short. This is the structural MRI volume on which we would like to segment the CC.

Options:

-verbose (-v)	Enables verbose mode
-version (-V)	Reports software version
-help (-h)	Prints help message
-o <output-prefix>	Prefix for naming output files (default: same as input image)
-n <integer>	Specifies the number of atlases to be used (default = 49).
-csv <csvfile>.csv	CC measurements (area, perimeter, etc.) will be appended to this file in comma-separated values (CSV) format (default = <output-prefix>.csv)
-Hampel (-H)	When this option is selected, the program subdivides the CC area according to the Hampel et al. [1] method. The 5 sub-areas are stored in the output CSV file. The sub-areas are visualized in the PPM format image <output-prefix>_cc_hampel.ppm (Fig. 1) and also saved in the NIFTI file <output-prefix>_cc_hampel.nii.
-Witelson (-W)	When this option is selected, the program subdivides the CC area according to the Witelson et al. [2] method. The 7 sub-areas are stored in the output CSV file. The sub-areas are visualized in the PPM format image <output-prefix>_cc_witelson.ppm (Fig. 2) and also saved in the NIFTI file <output-prefix>_cc_witenson.nii.
-png	Outputs *.png images in addition to the *.ppm images. Requires the *pnmtopng* program on your system. Otherwise, you may see some error messages.
-threshold (-t) <float>	Specifies the threshold to be used for label fusion. This number should be between 0 and 100 (default = 50). 50 means that at least 50 percent of the atlases must declare a voxel to be CC for the final label fusion.

-lm <landmarks-file>	A text file containing manually determined (i, j, k) coordinates of the AC, PC and VSPS (vertex of the superior pontine sulcus) landmarks in that order. When this file is supplied, automatic detection of these landmarks is suppressed. This is useful in cases when automatic landmark detection fails. We recommend using the AFNI software for manual identification of these landmarks. A video instruction for this can be found here.
-A <filename.txt>	Uses a pre-selected set of atlases specified in "filename.txt" instead of automated atlas selection. "filename.txt" is always the output of a previous *yuki* run, namely the output file "*_A.txt".
-cc <corrected_cc.nii>	This option is used when the out binary CC image is corrected manually and we need to recalculate the CC related measurements (area, circularity, etc.) for the corrected image. Typically, when there is an error in "output-prefix_cc.nii", we load the "output-prefix_msp.nii" in ITK-SNAP and overlay "output-prefix_cc.nii" as a segmentation. The segmentation is manually corrected and saved under a different filename, for example, "output-prefix_corrected_cc.nii". Then we run "yuki -cc output-prefix_corrected_cc.nii" to obtain the corrected CC measurements.
-T <filename.mrx>	Applies the transformation matrix in "filename.mrx" to reorient the subject volume in preperation for CC detection. This option disables automatic reorientation. The format of "filename.mrx" is the same as the "output-prefix_msp.mrx" transformation matrix.
-atlas (-a) <atlas>	Specifies the atlas set to be used (default: amir464). The other option is currently: babak628. The default is recommended.

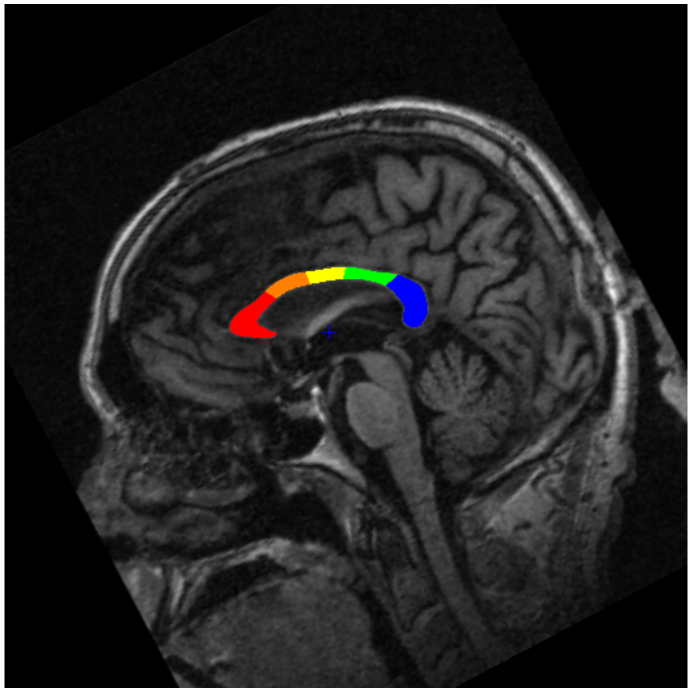

Figure 1: Five automatically detected CC sub-divisions as defined by Hampel et al. [1].

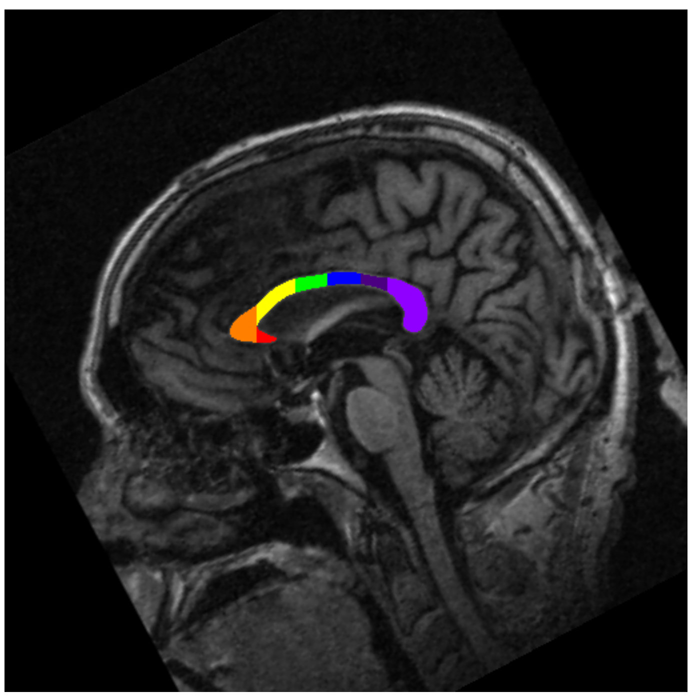

Figure 2: Seven automatically detected CC sub-divisions as defined by Witelson et al. [2].

Output files:

We will describe the program outputs after the following command:

yuki -i v1.nii -v -o op -H -W

Here the input image is "v1.nii", the output prefix is chosen as "op" and the program is asked to further subdivide the CC using both the Hampel (-H) and Witelson (-W) methods.

op.csv	CC measurements (area, perimeter, etc.) will be appended to this file in comma-separated values (CSV) format. The following measurements are stored: input volume, CC area (mm^2), CC perimeter (mm), CC circularity (unitless), CC length (mm), W1–W7 (Witelson sub-areas in mm^2), and C1–C5 (Hampel sub-areas in mm^2).
v1_ACPC_sagittal.ppm	Sagittal view of the detected AC/PC locations in PPM format (Fig. 3)
v1_ACPC_axial.ppm	Axial view of the detected AC/PC locations in PPM format (Fig. 4)
v1_orion.ppm	Mid-sagittal view of the detected "Orion landmarks" in PPM format (Fig. 5). The method for detecting these landmarks is described in [3].
v1_orion.txt	Stores (i, j, k) coordinates of the 8 detected "Orion landmarks" in voxel units.
v1_orion_PIL.txt	Stores the (posterior, inferior, left) coordinates of the 8 detected "Orion landmarks" in mm units following MSP and AC-PC correction.
v1_ACPC.txt	Stores the detected AC, PC and VSPS (i, j, k) coordinates. The equation of the automatically detected MSP is also saved in this file.
op_msp.mrx	A rigid-body linear transformation matrix (in ART format) that would transform the input image (v1.nii) to a tilt-corrected Posterior-Inferior-Left (PIL) orientation. Detailed information about how this matrix is obtained is given in [3].
op_msp.nii	A single slice NIFTI mid-sagittal plane (MSP) image obtained by applying op_msp.mrx to v1.nii. This is the image on which the CC is segmented.
op_cc.nii	A single slice binary NIFTI image representing the segmented whole CC on op_msp.nii.

op_cc.ppm	A PPM image in op_msp.nii orientation showing the results of CC segmentation. CC perimeter is indicated in yellow and cyan. An estimated medial axis is indicated in red. Some automatically detected landmarks are indicated by blue the + signs. An example is shown in Fig. 6.
op_cc_hampel.ppm	PPM format image aligned with op_msp.nii and op_cc.nii, output with -H option. The program subdivides the CC area according to the Hampel et al. [1] method. The 5 sub-areas are stored in the output CSV file. The sub-areas are visualized in this image (see Fig. 1).
op_cc_hampel.nii	NIFTI format version of op_cc_hampel.ppm output with -H option. The 5 sub-divisions are labeled from 1 to 5.
op_cc_witelson.ppm	PPM format image aligned with op_msp.nii and op_cc.nii, output with -W option. The program subdivides the CC area according to the Witelson et al. [2] method. The 7 sub-areas are stored in the output CSV file. The sub-areas are visualized in this image (see Fig. 2).
op_cc_witelson.nii	NIFTI format version of op_cc_witelson.ppm output with -W option. The 7 sub-divisions are labeled from 1 to 7.
op_A.txt	The list of automatically selected atlases. The default number of atlases is 49. This number can be changed using the -n option. The first line in the op_A.txt file indicates the number of atlases used. The subsequent lines indicate the indices of the automatically selected atlas. The last line indicates a threshold used for label fusion for obtaining the final CC segmentation. This file may be used later as an optional input to *yuki* to override the automatic atlas selection and label fusion threshold selection on a subsequent analysis.

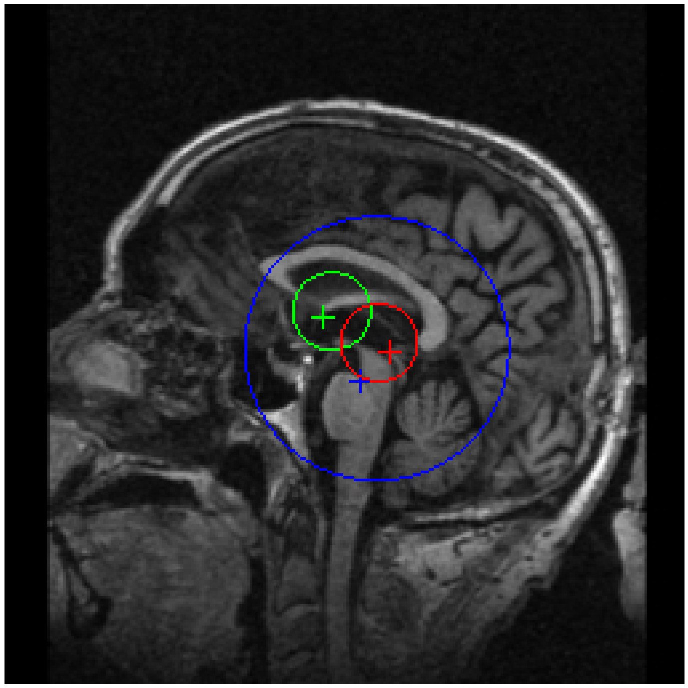

Figure 3: v1_ACPC_sagittal.ppm shows the automatically detected MSP, the AC (green +), the PC (red +) and the VSPS (blue +).

op_TP.txt	After CC segmentation, *yuki* attempts to measure the CC thickness profile. The estimated profile is stored in this file. This part of the program is a work in progress, and the output profile is sometimes not accurate. The op_cc.ppm image should be inspected to ensure that the CC medial axis is correctly detected. If so, then the thickness profile may be relied upon. op_TP.txt contains 101 numbers representing lengths (mm) of 99 line segments perpendicular to the medial axis along the length of the CC. The thicknesses of the first and last segments are always zero.
op_WACC.nii	The individual atlas labels after nonlinear warping are stored in this file. The number of atlases is specified by the -n option (default = 49). Label fusion is applied to these in order to obtain the final segmentation.

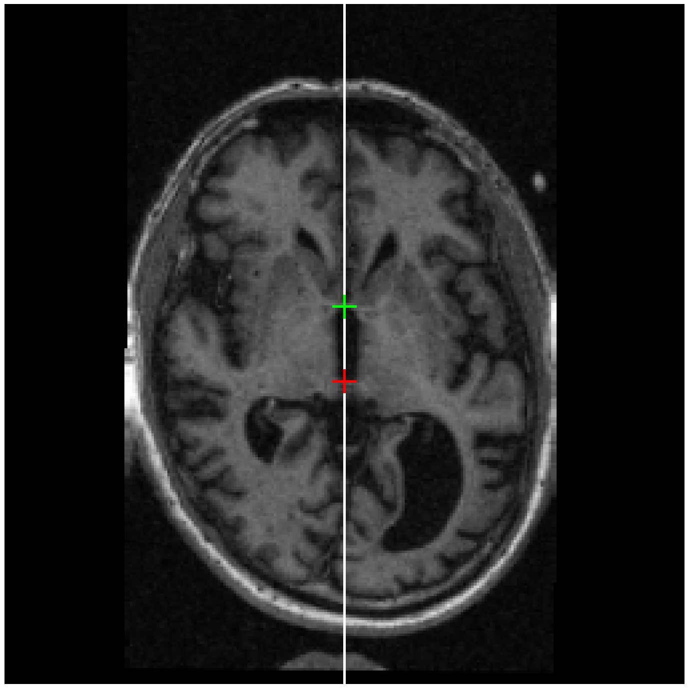

Figure 4: v1_ACPC_axial.ppm shows the automatically detected MSP, the AC (green +), the PC (red +).

Figure 5: v1_orion.ppm shows the 8 automatically detected "Orion landmarks" on the pitch-corrected MSP.

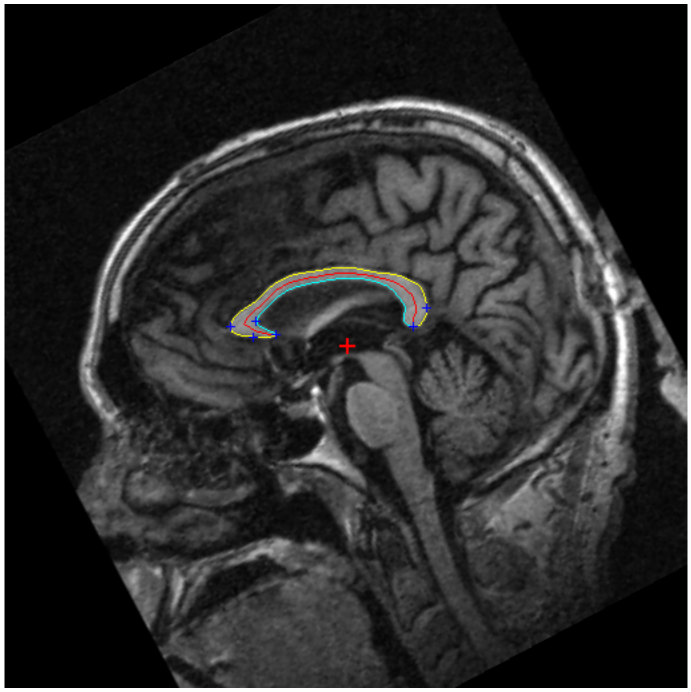

Figure 6: A PPM image in op_msp.nii orientation showing the results of CC segmentation.

Failure in landmark detection: It is strongly recommended that the *ppm images be inspected to ensure that the automatic MSP, AC, PC and VSPS detection was successful. If there is a failure in this process, the AC, PC and VSPS landmarks should be manually supplied to the program using the -lm argument. We recommend using the AFNI software for manual identification of these landmarks. A video instruction for this can be found here.

References

[1] H Hampel, S J Teipel, G E Alexander, B Horwitz, D Teichberg, M B Schapiro, and S I Rapoport. Corpus callosum atrophy is a possible indicator of region- and cell type-specific neuronal degeneration in alzheimer disease: a magnetic resonance imaging analysis. *Arch. Neurol.*, 55(2):193–198, February 1998.

[2] Daniel Narayan, Saul Rajak, Sandy Patel, and Dinesh Selva. Cystic change in primary paediatric optic nerve sheath meningioma. *Orbit*, 35(4):236–238, August 2016.

[3] B. A. Ardekani. A new approach to symmetric registration of longitudinal structural MRI of the human brain. *J Neurosci Methods*, 373:109563, May 2022.