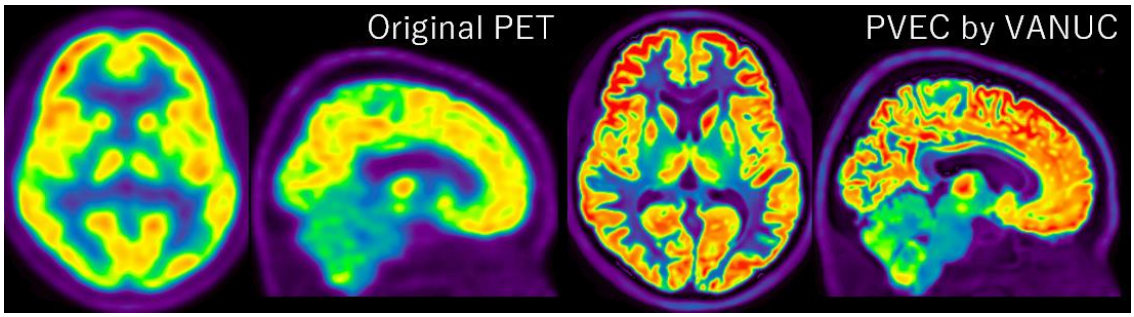
User Manual

VANUC: Voxel-wise Anatomical-region-based Non-Uniformity Correction for partial volume effects (version 2)



Overview

VANUC is a program for performing partial volume effect correction (PVEC) of PET and SPECT images using VANUC method[1].

- With a simple push of a button, VANUC reads image data, aligns it, corrects partial volume effects, and outputs standard brain coordinate images for statistical analysis.
- By inputting Hoffmann brain phantom PET images, the program can automatically calculate the parameters necessary for performing PVEC.

This program runs on MATLAB and requires SPM to be installed.
(Developer: Akira Arai)

1. Preparation before Use

1-1. Usage Environment

This software runs on the numerical calculation software MATLAB.

To use SPM12 functions, SPM12 download and path setting are required.

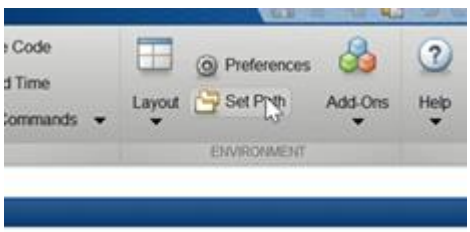
- Download SPM12 from website.
- After downloading, please set the path settings for SPM12 in MATLAB.
    1. Launch MATLAB.
    2. Open "ENVIRONMENT" > "Set Path" on the toolbar.
    3. Click "Add Folder..." and select "spm" folder, then click "Save".
    4. Close the Path Setting window, type "spm" in the MATLAB command window, and confirm that SPM12 starts up.

1-2. Download VANUC

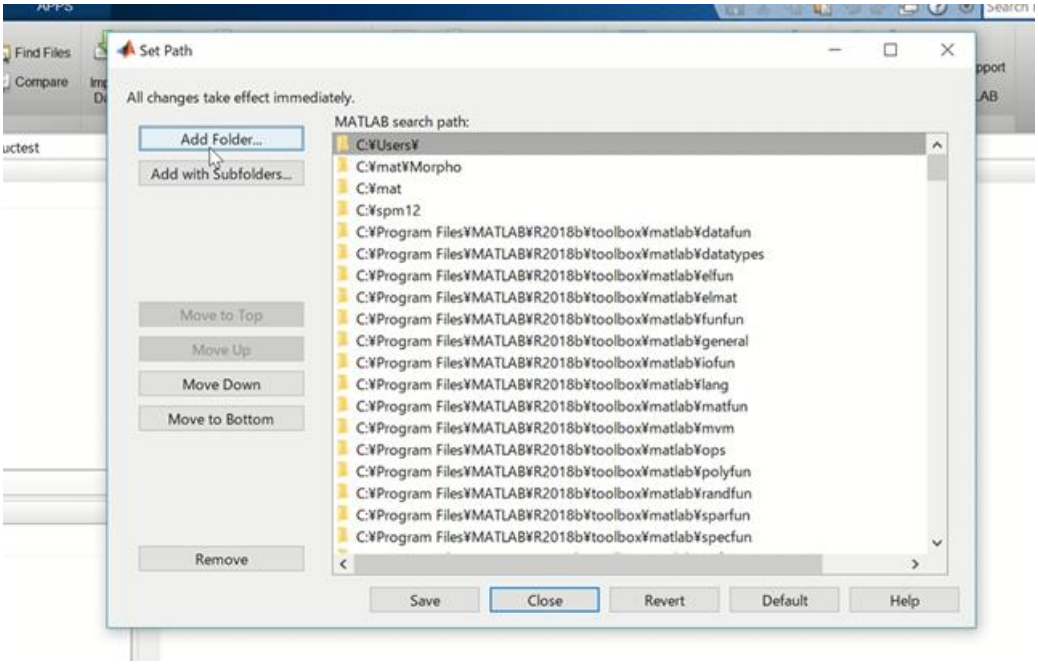
1. Click "Code" on this page (https://github.com/Akira-Arai/vanuc) and click Download ZIP to download all the files in the repository. Unzip the downloaded zip file.
2. Save the entire "vanuc-main" folder. To avoid errors, it is preferable to save the folder in a location such as directly under the C: drive.

1-3. Path Settings for VANUC

1. Launch MATLAB.
2. Open "ENVIRONMENT" > "Set Path" on the toolbar.



3. Click "Add Folder...". and select "vanuc-main" folder (the lowest one), then click "Save".



4. Close the Path Setting window, type "vanuc" in the MATLAB command window, and confirm that vanuc starts up.

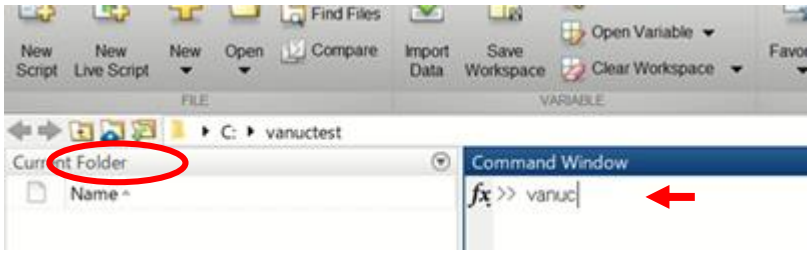
1-4. Image Preparation

- For partial volume effect correction process, etc.
    - Brain PET or SPECT and brain 3D-T1-weighted images are required.
    - DICOM or NIfTI formats are supported.
        - Conversion to SUV on PET images is only possible with DICOM format images.
- For phantom images
    - Only DICOM format is supported at this time.
- For other formats or images that cannot be read by this software
    - Please use other software to convert to NIfTI format.

2. How to Use

2-1. Execution of VANUC Program

- Enter "vanuc" in the MATLAB command window to open the GUI of VANUC.

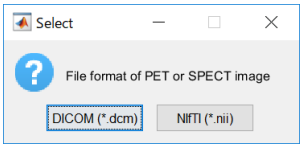


- Processed images and other data will be output in the "current folder" of MATLAB, so change the output destination accordingly.

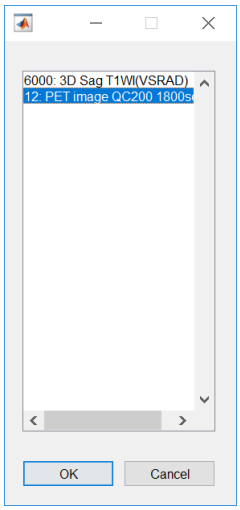
Partial Volume Effect Correction Tool

- Corrects partial volume effects using the VANUC[1], Muller-Gartner[2] and RBV[3] methods, and outputs the corrected data and images.

1. Click **"Start"** button.
2. **Select PET or SPECT image.** If you want to convert PET to SUV values, load "DICOM" data.

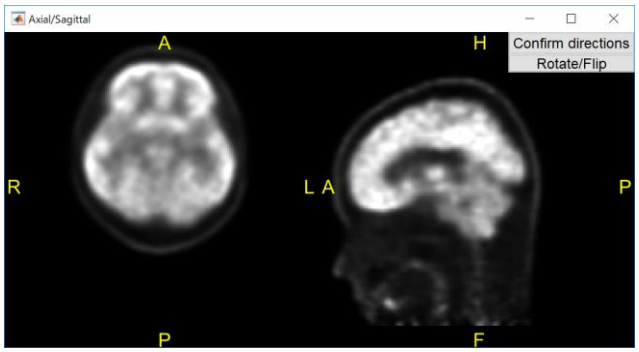


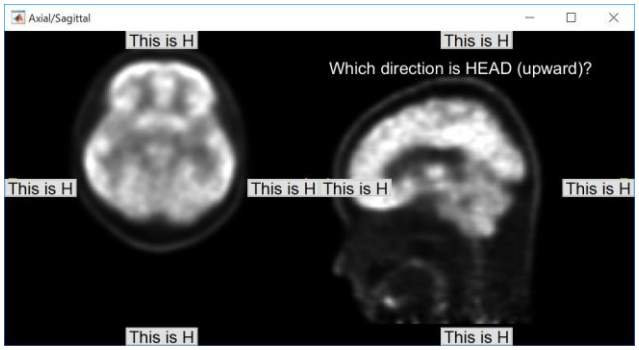
- If "DICOM" is selected:
    1. Select the folder under that the DICOM files are stored.
    2. Select the target image from the list of DICOM data in the folder and subfolders.



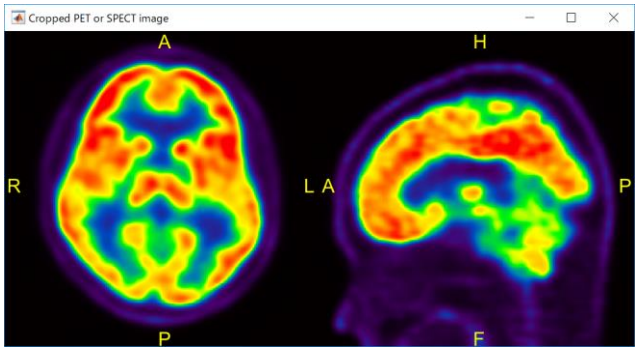
- If "NIfTI" is selected:
    1. Select the NIfTI file.
    2. Select whether or not cropping (cutting off the parts other than the head) should be performed. Normally, select "OK", but if cropping has already been performed, select "Skip".

3. **Align the orientation of the image.** If the image directions and the H (up), F (down), A (front), P (back), R (right), and L (left) are matched, click "Confirm directions". If not, click "Rotate/Flip" and follow the directions in the order shown: up, forward, left and right.

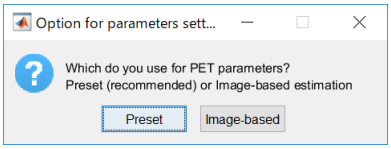




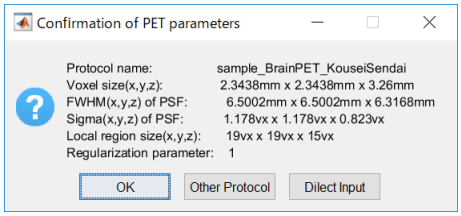
4. **Cropping** The cropped image will be displayed in color.



   - If cropping does not work:
     1. Stop the program.
     2. If necessary, use other software to crop the NIfTI file (in the case of PET, the file begins with SUV_) that was output in step 3.
     3. Run the process again, select the created image file as PET or SPECT image, and Skip Cropping.
5. **Set PET parameters.** Select whether to preset values (Preset) or to estimate from the image (Image-based). Normally, "Preset" is recommended.



- If "Preset" is selected:
  - The parameter values that were used the last time (default values for the first time) are first displayed. If you need to change the parameters, you can either select from the protocols saved in advance (Other Protocol) or directly input them (Direct Imput). The value entered by "Direct Imput" can be saved as a new protocol and selected the next time. If you want to determine parameters from phantom data, see below.



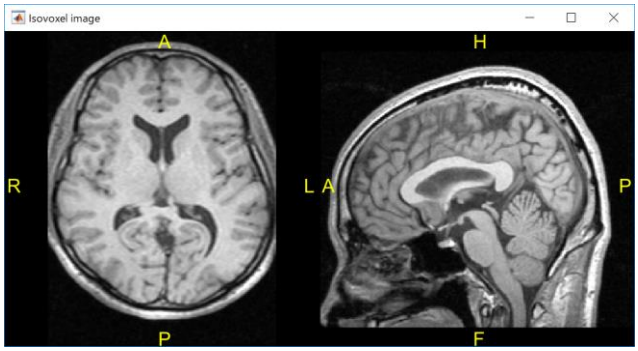
  - Explanation of setting values:

    FWHM of PSF:

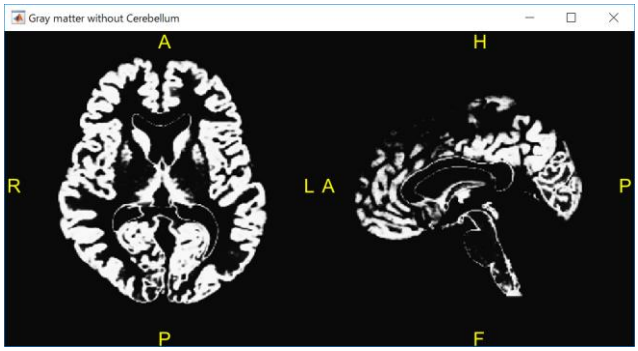
    Full width at half maximum (mm) of the point spread function of the PET image (x: left to right, y: front to back, z: up and down).

    Distance from center of local region: Distance (in voxels) from the center voxel to the edge of the kernel used in the VANUC method. Normally, the default value is sufficient, but if the resolution is low and there is a lot of noise, a larger value should be set. Note that larger values increase processing time. Regularization parameter: Regularization parameter used in the VANUC method. For clinical PET and SPECT images, the value is between 1 and 100. If the noise is large, a larger value should be used. Strictly determined by L-curve analysis, etc.

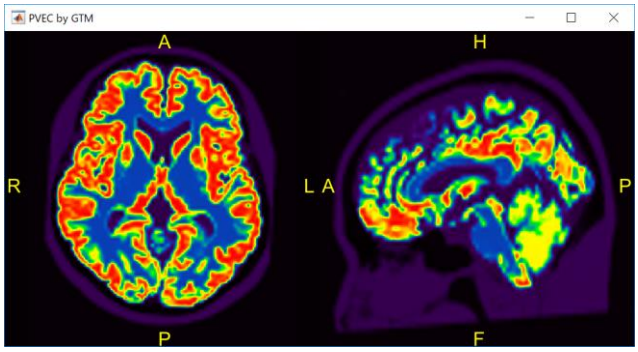
6. Select **a 3D T1-weighted image** , orient the image, and cropping is performed.（same as above for PET or SPECT).



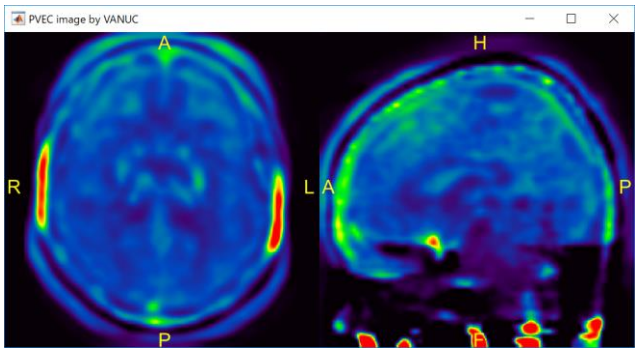
7. Partial volume effect correction begins and takes 10 to 30 minutes. (During the process, if the TPM file (tissue probability map) is not found in the designated location in the SPM folder, you will be asked for the file location.)
    - In process – segmentation



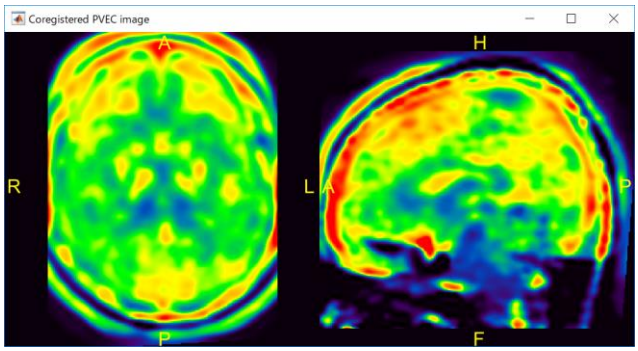
    - In process – GTM[4] correction



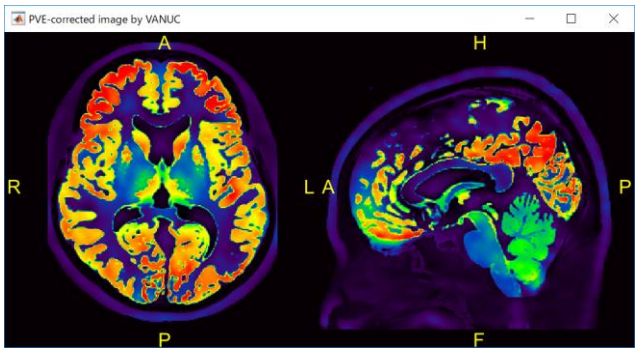
- In process – output PVEC images



- In process – normalize to MNI space



- In process – output composite PVEC images



Phantom Data Analysis Tool

- Tool to determine PET parameters needed for partial volume effect correction

1. Click on "Phantom."

2. Select the folder where the phantom images (DICOM) are stored and select the target phantom image from the list.
3. Orient the phantom image. (Same as above)
4. Select a digital phantom; the data for the Hoffman 3D brain phantom is pre-populated.
5. Analysis takes a few minutes.
6. The FWHM of PSF value is obtained, and the other parameters and the protocol name are entered and saved as a new protocol. If you do not want to save it, click "Cancel" to exit. Once saved, the parameter settings of the saved protocol can be used for the next partial volume effect correction.

Other Processing Tools

- dcm>nii: DICOM to NIfTI conversion (including conversion to SUV values for PET)
- Orientation: Transformation of image orientation (e.g., rotation, left/right flip, etc.)
- Crop: Cutting the image except for the head (Orientation is processed first)

2-2. Output Data Lists

Partial volume effect correction output data

List in the current folder (main output images such as images in process and partial volume effect corrected images):

Data Name	Description
PT~.nii or NM~.nii	Original PET or SPECT image
SUV_PT~.nii	Converted image to SUV values (only for PET)
trim_PET.nii	PET (or SPECT) image after cropping
MR~.nii	Original MRI image
T1.nii	MRI image after cropping
coT1.nii	isovoxel MRI image
coT1_seg8.mat	Segmentation data by SPM
c1~6coT1.nii	Maps of gray matter, white matter, cerebrospinal fluid, skull, soft tissue, and air

y_coT1.nii	transformation field from MRI coordinates to MNI standard brain coordinates
c1acoT1.nii	cerebellar gray matter map
c1bcoT1.nii	map of gray matter other than cerebellum
rcoT1.nii	MRI image coregistered to PET (or SPECT)
rtrim_PET.nii	PET (or SPECT) image coregistered to MRI
PVCvanuc.nii	Partial volume effect corrected image (7 regions) using VANUC method
PVCmg.nii	Partial volume effect corrected image (7 areas) using Muller-Gartner method
PVCrbv.nii	Partial volume effect corrected image (7 areas) using RBV method
rPVC~.nii (3 types)	Partial volume effect corrected images (7 areas) coregistered to MRI
PVCC~.nii (3 types)	Partial volume effect-corrected images composited from all 7 regions
PVRC~.nii (3 types)	Partial volume effect "reduced" images (FWHM 2.5mm) composited from all 7 regions

List in MNIspace folder (images converted to MNI standard brain coordinates, used for statistical image analysis by SPM, etc.):

Data Name	Description
wcoT1.nii	Anatomical standardized MRI image
wrtrim_PET.nii	Anatomical standardized PET (or SPECT) image (SUV values for PET, original values for SPECT)
wrPVC~.nii (3 methods x 3 regions)	Anatomically standardized partial volume effect corrected image (cerebellar gray matter, other gray matter, white matter)
wrPVC~_cbl.nii (3 methods x 3 regions)	Anatomical standardized partial volume effect corrected images normalized by cerebellar gray matter values
wrPVC~_gm.nii (3 methods x 3 regions)	Anatomical standardized partial volume effect corrected images normalized by gray matter values
wrPVC~_wb.nii (3 methods x 3 regions)	Anatomical standardized partial volume effect corrected images normalized by whole brain values

List in temp folder (raw data of partial volume effect correction):

Data Name	Description
Ppsf.mat	Parameters for point spread function
Ploc.mat	Parameters for kernel size in VANUC method

Plam.mat	Parameters for regularization in VANUC method
G.mat	PET (or SPECT) voxel values
M.mat	Tissue map data of 7 regions obtained by MRI segmentation
V.mat	Region spread function (RSF) of 7 regions
Rgtm.mat	Correction values for partial volume effect in 7 regions by GTM method
Rols.mat	Expected value component of 7 regions by VANUC method
Rvanuc.mat	Partial volume effect corrected image data of 7 regions by VANUC method
Rmg.mat	Partial volume effect corrected image data of 7 regions by Muller-Gartner method
Rrbv.mat	Partial volume effect corrected image data of 7 regions by RBV method
Voxel.mat	Voxel size parameters

Phantom data analysis output data

Data Name	Description
PT~.nii or NM~.nii	Original PET or SPECT image
SUV_PT~.nii	Converted image to SUV values (only for PET)
roSUV_PT~.nii	PET (or SPECT) image after reorientation
crop_roSUV_PT~.nii	PET (or SPECT) image after cropping
DigitalPhantom.nii	Original digital phantom image
rc~Phantom.nii	Digital phantom image coregistered with PET (or SPECT)
Phantom.mat	G: original PET (or SPECT) values, R: true distribution, M: phantom composition.

4. Cautions for Use

When presenting the results obtained by using this software in scientific journals or at conferences, etc., please clearly state the name of the software, etc.
The developer is not responsible for any damage caused by the use or malfunction of this software.
Please read license file for license terms.

5. References

1. Akira Arai, Yuriko Kagaya, Kentaro Takanami, Kei Takase. A novel partial volume effect correction method which allows for heterogeneous distribution: The potential advantages in the white matter activity estimation on FDG-PET. J Nucl Med. 2016;57(supplement 2):1924
2. H W Muller-Gartner, J M Links, J L Prince, R N Bryan, E McVeigh, J P Leal, C Davatzikos, J J Frost. Measurement of radiotracer concentration in brain gray matter using positron emission tomography: MRI-based correction for partial volume effects. J Cereb Blood Flow Metab. 1992 Jul;12(4):571-83
3. Benjamin A Thomas, Kjell Erlandsson, Marc Modat, Lennart Thurfjell, Rik Vandenberghe, Sebastien Ourselin, Brian F Hutton. The importance of appropriate partial volume correction for PET quantification in Alzheimer's disease. Eur J Nucl Med Mol Imaging. 2011 Jun;38(6):1104-19
4. O G Rousset, Y Ma, A C Evans. Correction for partial volume effects in PET: principle and validation. J Nucl Med. 1998 May;39(5):904-11