

Scalable Alignment of Electron Microscope Image Sections

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■ Goals

- Scalable alignment of 3D Electron Microscope sections of mouse brain.
- Integration with CAJAL-3D API for easy image retrieval and upload from database.

■ Difficulties

- Approach must be scalable.
- ($1024 \times 1024 \times 2000$ in the smallest data set $\approx 2B$ voxels.)
- Most datasets occupy TB of space; infeasible to align all at once.

■ General Method

- 1 Compute the transformations for alignment between adjacent pairs of images using cross-correlation.
- 2 Globally align an entire image cube using pairwise transformation parameters.

Pairwise Alignment

Objective: Compute the transformations necessary to align adjacent pairs of images.

Outline of procedure:

- 1 Compute pairwise transformation parameters.
- 2 Improve rotation parameter through error minimization.
- 3 Refine transformations using image data outside pairwise images to minimize error.

Pairwise Alignment

Compute Pairwise Transformation Parameters

Objective: Determine the transformations necessary to align image pair.

For each pair of images:

- 1 Apply median filtering, histogram equalization, and hamming window.
- 2 Take Discrete Fourier Transform, apply high-pass filter, and resample in log-polar coordinates.
- 3 Find best ρ , θ by correlation and max picking.
- 4 Rotate image, then correlate to find the best translation parameters.
- 5 Use Support Vector Machine (SVM) to identify peak in cross-correlation of image pair.
- 6 Save the transformation parameters.

Pairwise Alignment

Peak Identification

Objective: Determine peaks in the cross-correlation of two images that correspond to translations for correct alignment.

- 1 Train SVM classifier with selected peak features from already aligned images (ground truth).
- 2 Partition cross-correlation of pairwise images into 9 equal parts.
- 3 Find the coordinate of maximum intensity point in each partition.
- 4 Sort the coordinates with respect to maximum intensity.
- 5 Classify each of the 9 potential peaks in descending order until a peak is found.
- 6 If none of the peaks are classified as peaks, then no peaks detected.

Other Attempted Methods:

- Choose maximum values.
- Correlate pairwise cross-correlation with normal distribution

Pairwise Alignment

Improve Rotation Parameter

Objective: Evaluate the correct alignment rotation with a finer level of discretization.

- 1 Given initial estimate of rotation angle θ necessary to align images...
- 2 Iterate for each k over a small window $\theta_{new} = [\theta - k\epsilon, \theta + k\epsilon]$, in increments of ϵ .
- 3 Compute alignment error with θ_{new} as rotation angle.
- 4 Update rotation parameter with angle that minimizes Mean Squared Error (MSE) between image pair.

Pairwise Alignment

Refine Transformation Parameters

Objective: For alignment of image pair I_2, I_3 , use data from images I_1 and I_4 .

- 1 Calculate pairwise transformation parameters between I_1, I_3 and I_2, I_4 .
- 2 Obtain 2 more estimations of transformation parameters between I_2, I_3 using new information.
- 3 Determine the Mean Squared Error between image pair using all estimates of transformations.
- 4 Pick transformation that minimizes error.

Global Stack Alignment




Objective: Given transformation parameters between all adjacent image pairs, compute transformation to each image in global coordinate frame.

- 1 Set global transformation parameters of previous image to that of current image.
- 2 Find new rotation angle by adding previous rotation parameter to pairwise rotation angle.
- 3 Find new translation parameters using previous rotation angle and pairwise translations.
- 4 Positive translations: shift current image. Negative translations: shift all previous images.
- 5 Iterate through image cube to globally align stack.

Other Attempted Methods

- RANSAC to detect linear folds
- SURF feature matching to align images
- Superpixels and Earth Mover's Distance as a better error metric for image alignment

References

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