Metrics for Comparing 3D Neuron Segmentations in Expansion Microscopy Connectomics

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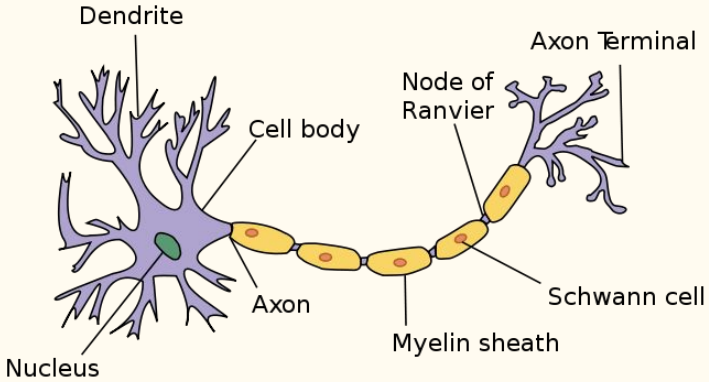
Background Information

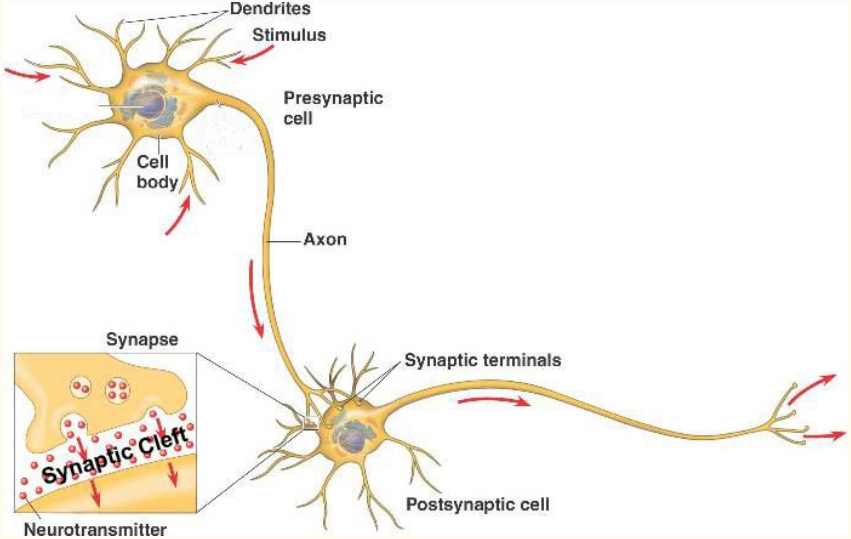
Neurons

- Functional unit (cell) of the nervous system
  - Convey information in the brain
  - Electrical and chemical signals
- Provide foundation for brain function
  - Understanding the brain



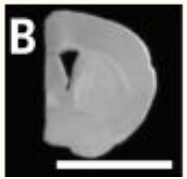
Synapses

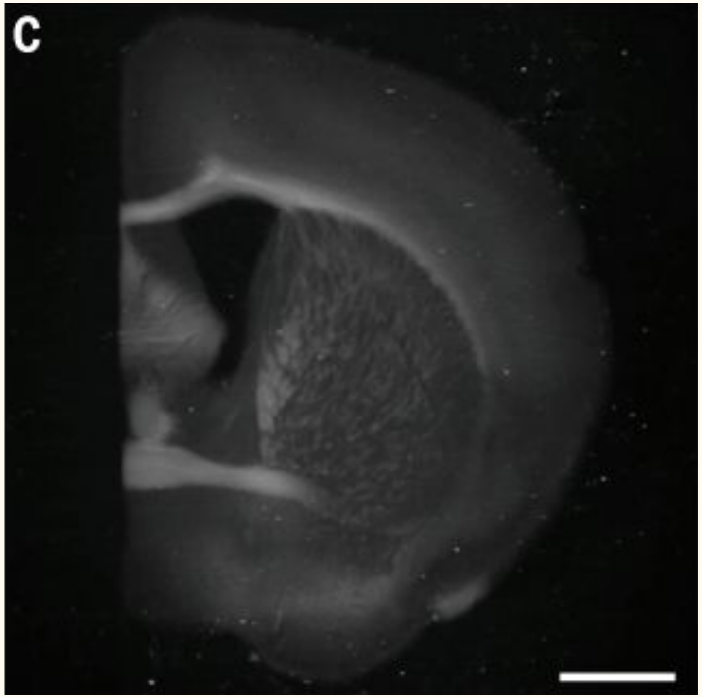
- Connections between neurons
  - Signals transferred
- Knowing shape of neuron would help track signals
- Looking at individual neurons for now
  - Multi-cell connected networks later



Expansion Microscopy Connectomics

- Study of comprehensive maps of connections in the nervous system
- Traditional light microscopy up to 300nm
- Expansion microscopy works by physically expanding tissue
  - Allows large 3D images at high resolutions
  - Color
  - 5x can see down to 60nm

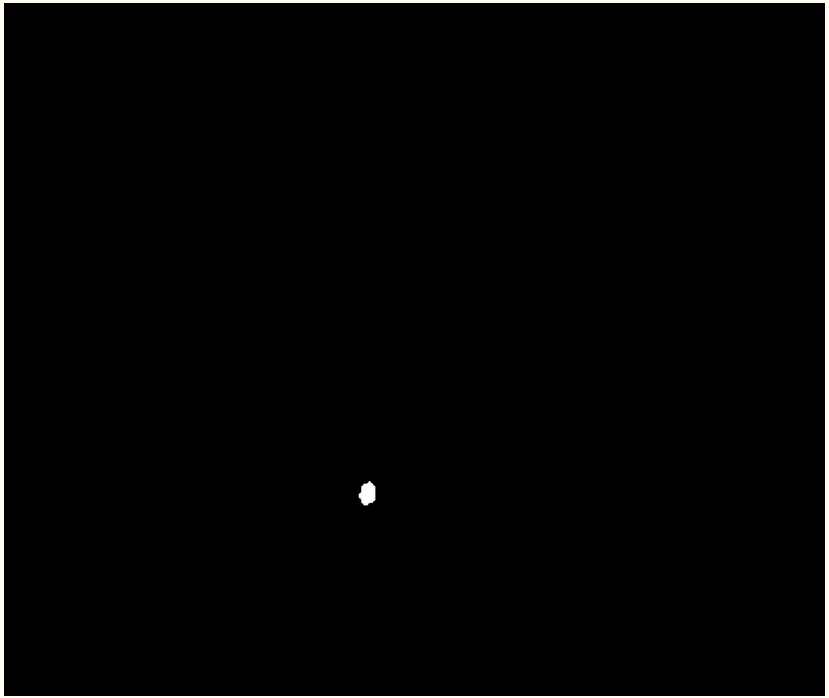




(Chen, Tillberg, Boyden 2014)

Segmentation

- Finding and isolating shape of individual neuron(s)
- Laborious for humans, computers would accelerate process
- Difficulties with misleading background “noise,” isolating individual neuron



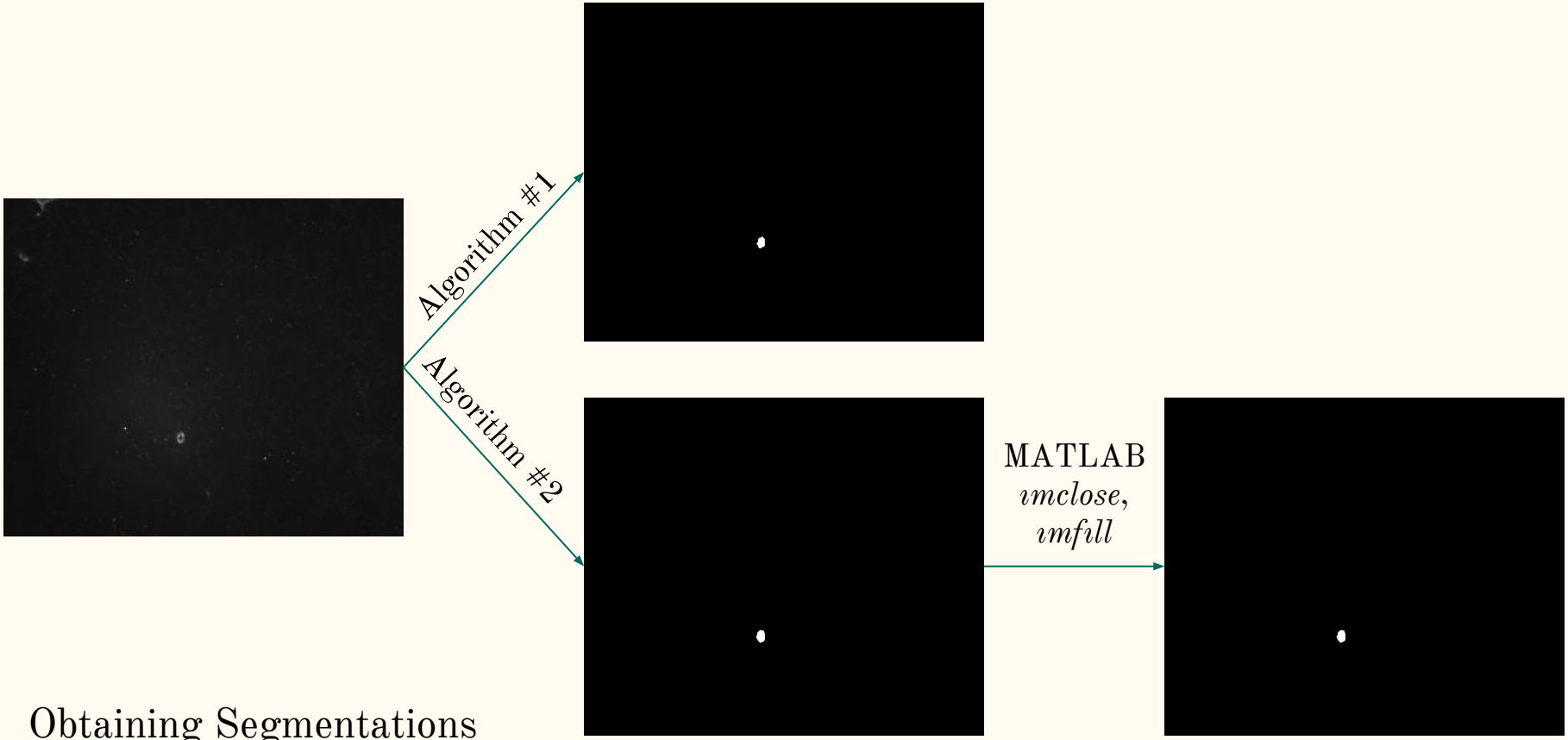
Goal

- Implement metrics to evaluate the performance of a computer algorithm at segmenting neurons in 3D
- Ultimately find the best segmentation algorithm

1. Raw Data

2. Segmentations

3. Adjusted



Obtaining Segmentations

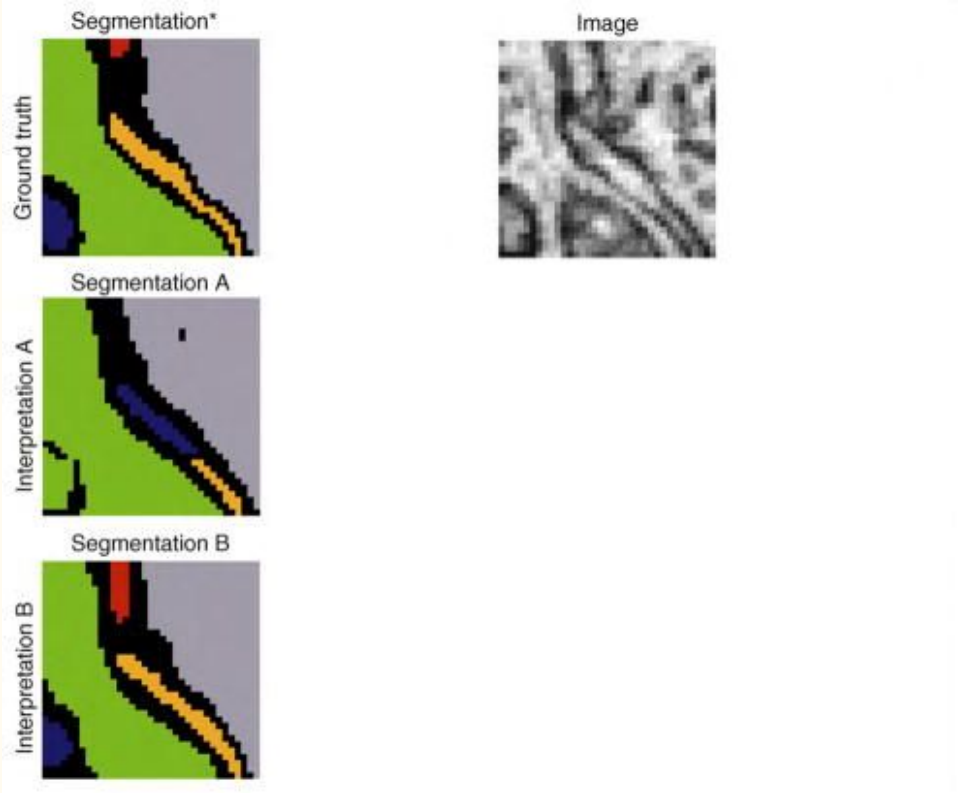
Metrics of Segmentation Performance

Metrics of Segmentation Performance

- Compare segmentation from computer vs. human (“ground truth”)
- Error types: deletion, split (incorrect boundary), merger (incorrect gap)
- Ideal metric: tolerate minor differences, strongly penalize splits/mergers (topological disagreements)

Evaluation metrics:

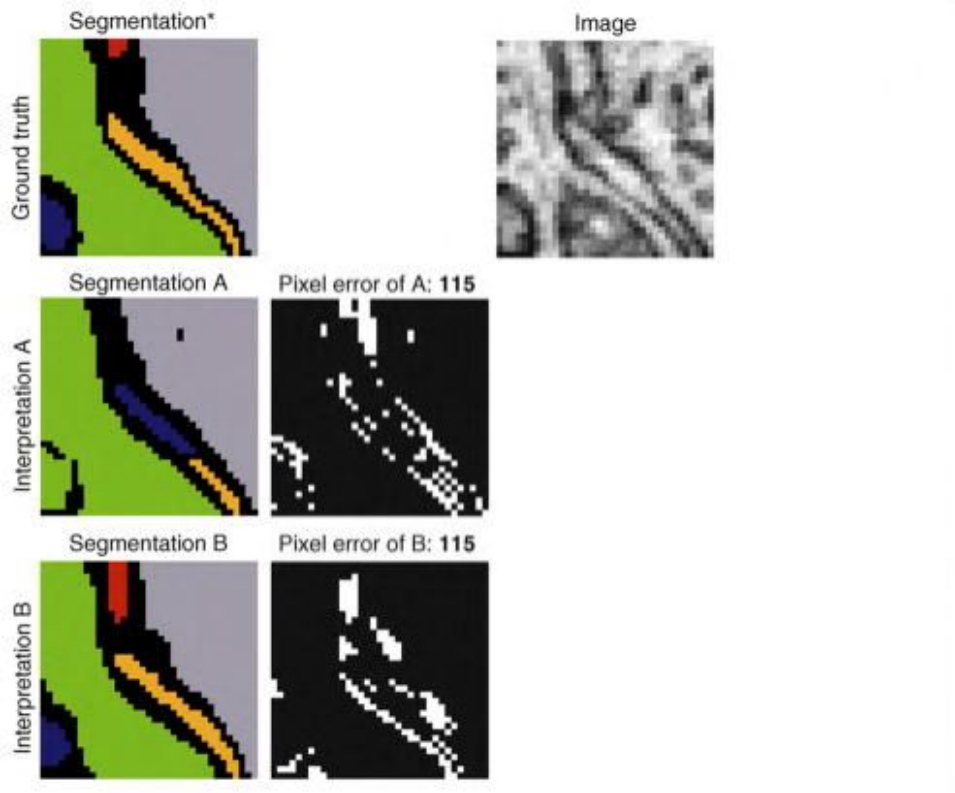
- *Pixel error* - count number of pixels where computer disagrees with human
  - Misleading, fails to notice intuitive disagreements
- *Rand error* - fraction of pixels pairs that belong to same region in one segmentation but not other
- *Warping error* - count of topologically-relevant boundary labeling errors



- Human interpretation
- Contains deletion, split, and merger
- Contains no serious errors

(Jain, Seung, Turaga)

Visual comparison of evaluation metrics



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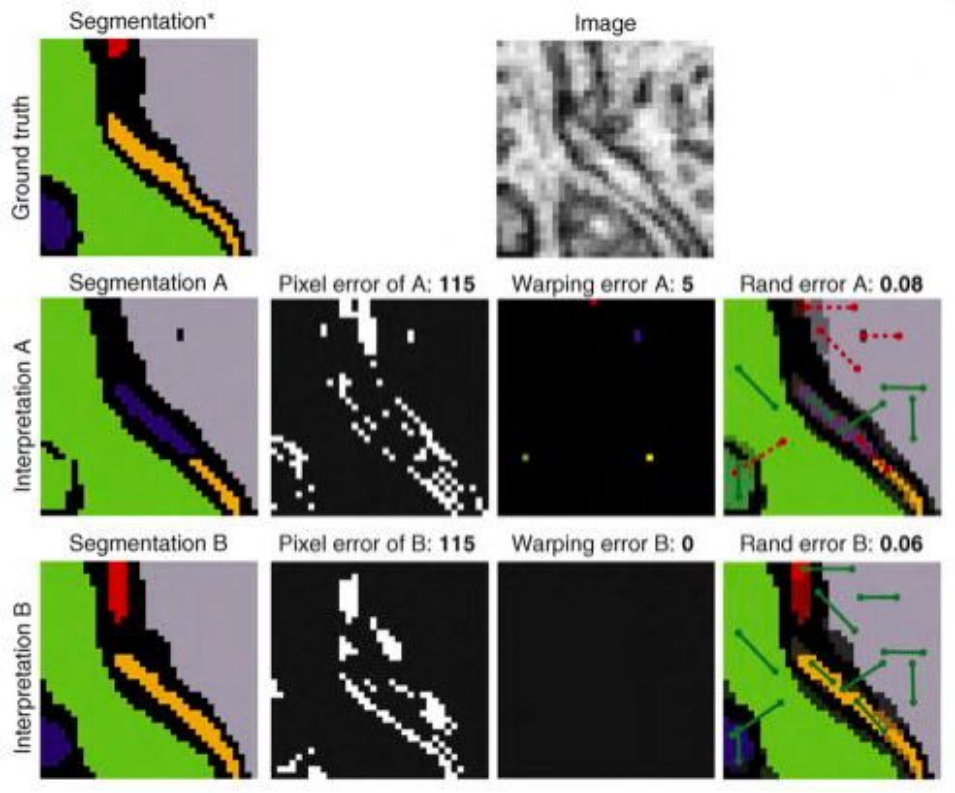
Visual comparison of evaluation metrics



(Jain, Seung, Turaga)

Visual comparison of evaluation metrics

- Human interpretation

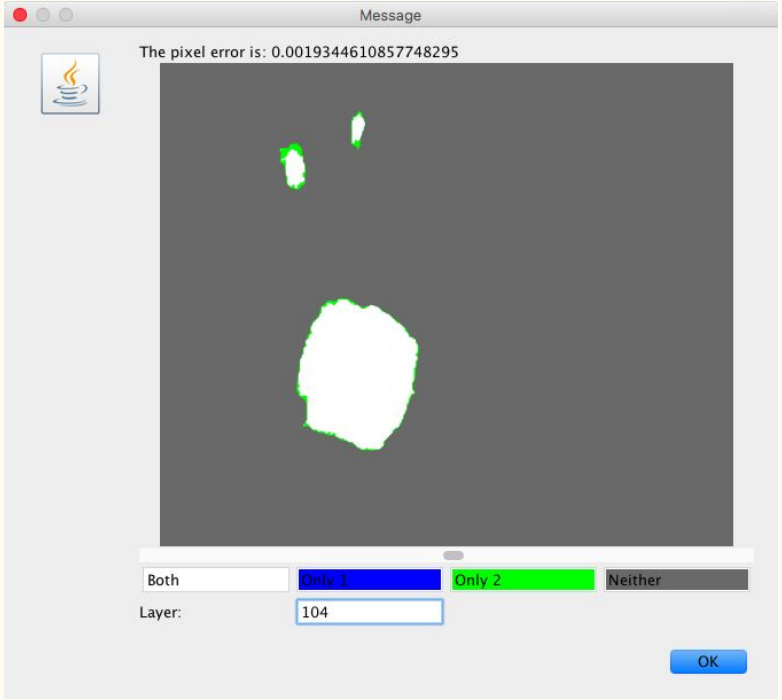
- Contains deletion, split, and merger
- *Pixel error* misleading

- Contains no serious errors
- *Warping error* and *Rand error* much better representation

Developing an Application

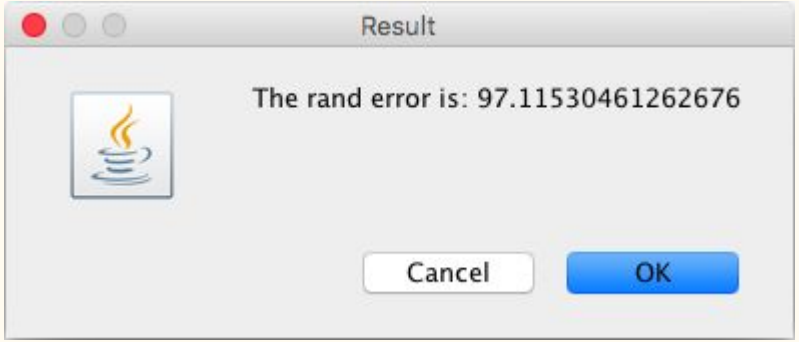
Working with Pixel Error

- *Pixel error* - count number of pixels where computer disagrees with human
- Wrote program in Java
- Able to:
  - Give score as decimal
  - Visualize error
    - See where segmentations differ
    - Provide feedback for developers of algorithms
  - Export result as TIFF



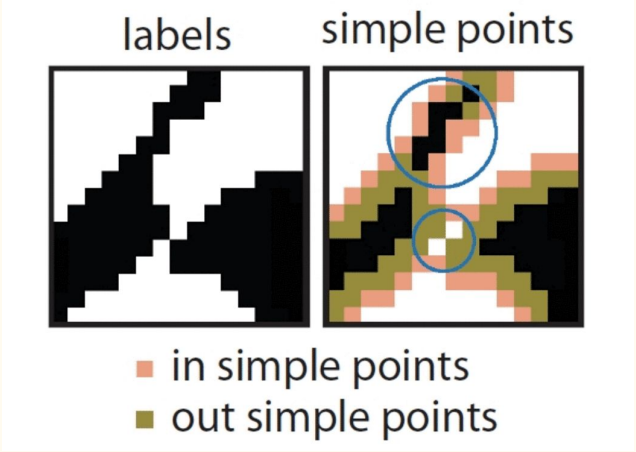
Working with Rand Error

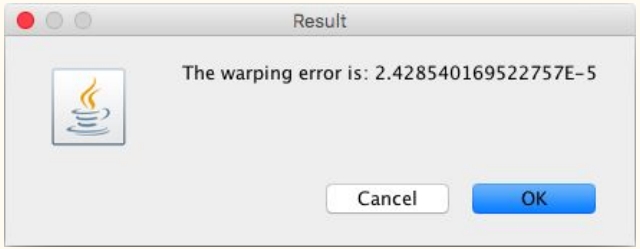
- *Rand error* - fraction of pixels pairs that belong to same region (connected component) in one segmentation but not other
- Able to:
  - Give score as decimal
- Improvements:
  - Solve accuracy issues
  - Generate visualization



Working with Warping Error

- *Warping error* - fraction of topologically-relevant boundary labeling errors
- Able to:
  - Give accurate score as decimal
- Improvements:
  - Generate visualization
  - Improve speed (currently ~10 min to run)





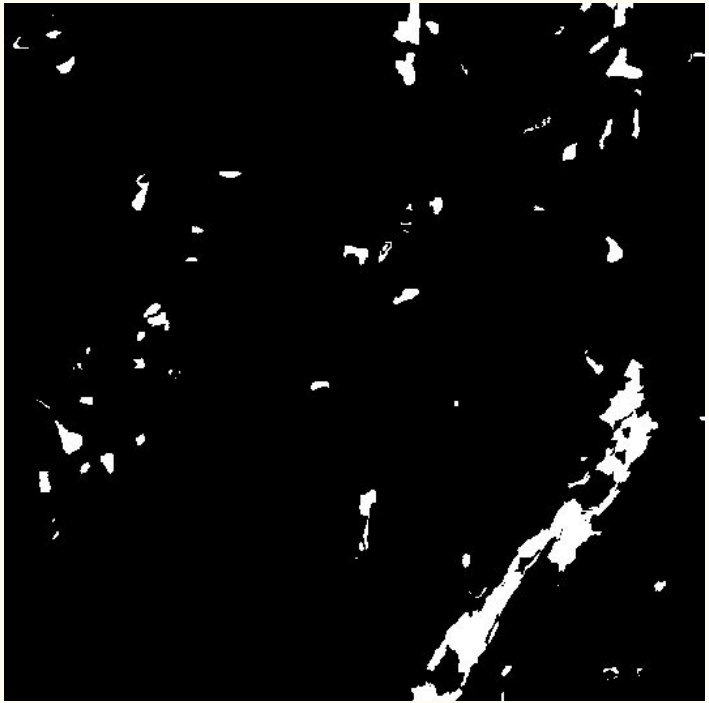
Conclusions

Results

- Wrote program able to compare two segmentations with pixel, rand, and warping error
  - Visualize/export pixel error
- Applied application to expansion microscopy data
  - Converted segmentations to common format (TIFF image)
- Ongoing: Collaborating with Boyden Lab researchers to provide feedback for algorithms

Future Plans

- Visualize results of Rand and Warping error
  - Provide better feedback for algorithm developers
- Add capability to evaluate multi-cell segmentations
- Automate scoring and improving algorithms



Multi-cell segmentation courtesy of Nick Barry (Boyden Lab)

Sources

- http://expansionmicroscopy.org/15.01.chen.FULL.pdf
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2975605/#S7title
- imagej.net/Topology_preserving_warping_error
- https://www.sfn.org/~/media/SfN/Documents/Short%20Courses/2011%20Short%20Course%20II/2011_SC2_Seung.ashx

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