Multilevel Aggregation for Image Segmentation

Rachel Tutmaher, James Folberth, and Nathan Heavner

April 27, 2015

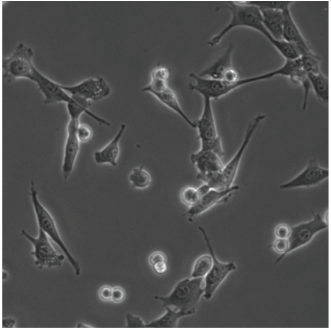
What is Image Segmentation?

- Process of subdividing an image into aggregates, aka "salient" segments.
- Use algorithms to automate the location, classification, or tracking of specific objects within the original image.
- Each of the pixels in a region that has been deemed "salient" should have similar properties; e.g. color, intensity, texture.
- Examples: Object Detection, Recognition Tasks, Medical Imaging.

“Multilevel Space-Time Aggregation for Bright Field Cell Microscopy Segmentation and Tracking."

Tiffany Inglis, et.al. *International Journal of Biomedical Imaging,* Volume 2010, Article ID 582760

- Large amounts of data.
- Cells have two different basic shapes and may be touching or overlapping.
- Automatic segmentation and tracking of live cells is a difficult task but vital to live cell studies.
- Bright field microscopy is well-suited for live cell studies; allows for study of cell morphology and internal cell structure and their dynamics.

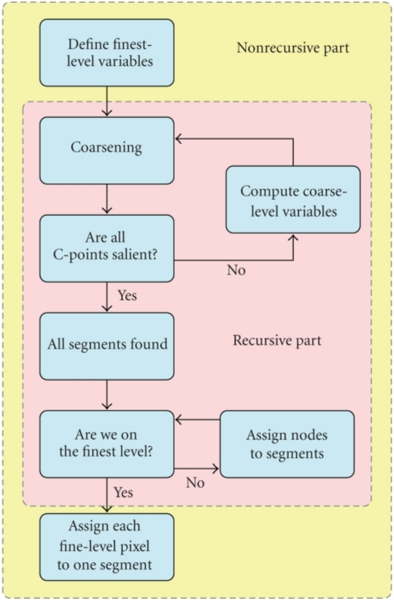


Algorithm Description

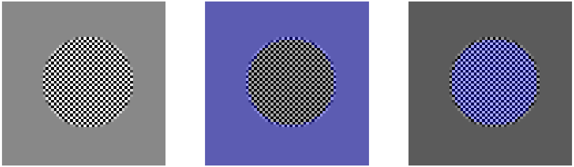
- Each pixel in image is scaled so that maximum intensity value is 1.
- Problem is analogous to that of a weighted undirected graph: Pixels represent nodes, edge determined by similarity of intensity with neighboring nodes.
- Edge weights determined by coupling matrix:

$$A_{ij} = \begin{cases} e^{\alpha \left| I_i^{[1]} - I_j^{[1]} \right|} & \text{if i, j are neighbors} \\ 0 & \text{else} \end{cases}$$

- Pixels recursively grouped: At any point blocks that are sufficiently different from their neighbors are identified as "salient" segments.
- Stop coarsening when all blocks are "salient"
- Bottom-up Phase: Uniquely assign all finest-level pixels to one of the segments.



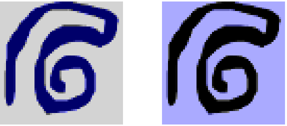
- Initially, weights in the coupling matrix A are based on the average intensity of the block
- The authors' algorithm scales the weights according to the similarities between two blocks' multilevel variance.
- This scaling makes it more likely for adjacent blocks with similar textures to be grouped together in subsequent levels.



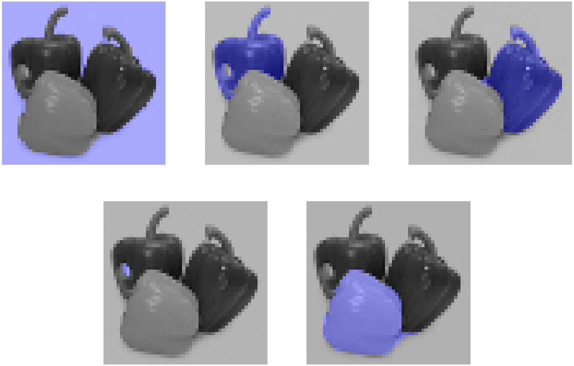
Results: Scale Invariant Saliency Measure

- The saliency measure $\Gamma_i^{[r]} = \dfrac{L_{ii}^{[r]}}{(1/2)W_{ii}^{[r]}}$ can be interpreted as the sum of the coupling coefficients along the border of block *i* divided by the sum of the coupling coefficients along connections internal to block *i*.
- Observe that this saliency measure is neither shape nor scale invariant.
- The authors make the saliency measure scale invariant by normalizing the weighted boundary length by dividing it by the unweighted boundary length; similarly for the area.

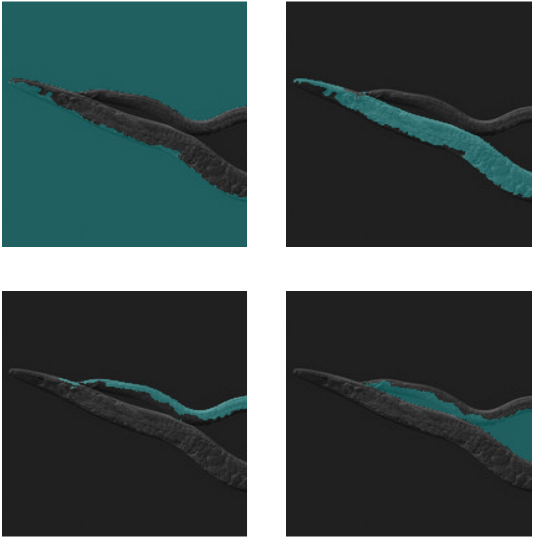
Segmentation without scale invariant saliency measure.



Segmentation with scale invariant saliency measure.

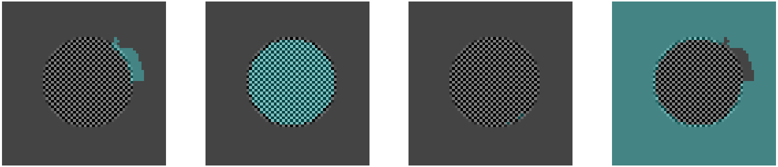


C. Elegans.

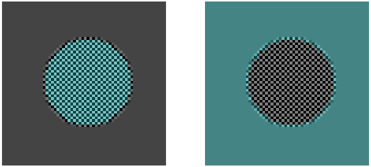


A few implementation details

Our implementation of the segmentation algorithm failed the checkered disk test case!
The authors of the segmentation algorithm specified parameters to use.

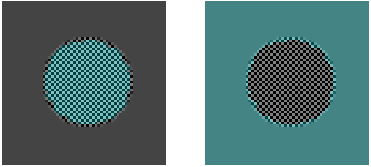


Inglis coarsener with off-diagonal row sum strengths.

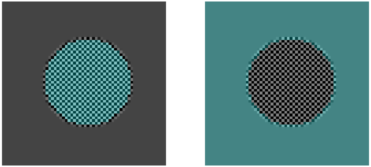


Ruge-Stüben coarsener with off-diagonal row sum strengths.

Our implementation of the segmentation algorithm failed the checkered disk test case!
The authors of the segmentation algorithm specified parameters to use.

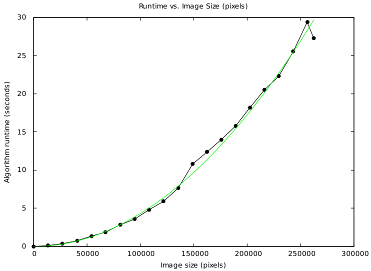


Inglis coarsener with maximum off-diagonal element strengths.

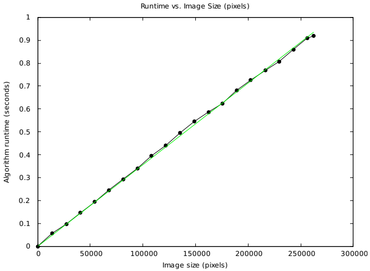


Ruge-Stüben coarsener with off-diagonal row sum strengths.

The segmentation algorithm uses a graph coarsener that is very similar to Ruge-Stüben AMG. The coarsener in RS AMG scales linearly with problem size. The segmentation algorithm, as written, appears to scale quadratically with problem size!



Inglis coarsening.



Ruge-Stüben coarsening.