Multilevel Aggregation for Image Segmentation

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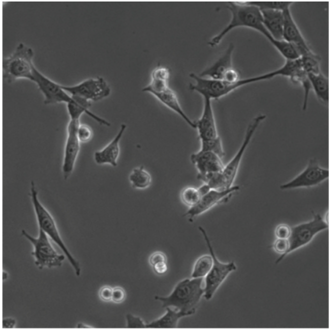
What is Image Segmentation?

- 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

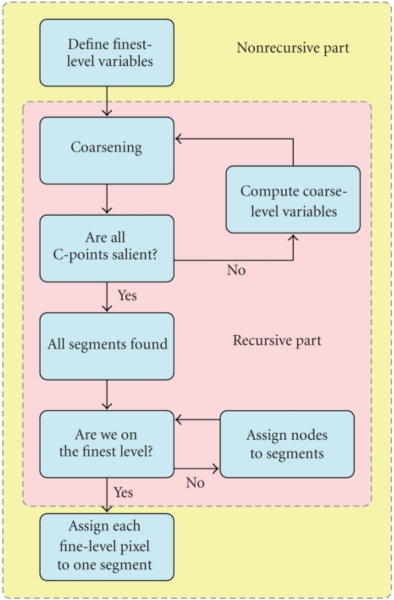
- Large amounts of data.
- Cells have two different basic shapes and may be touching or overlapping.
- Automatic segmentation and tracking of live cells is a difficult task but vital to live cell studies.
- Bright field microscopy is well-suited for live cell studies; allows for study of cell morphology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



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

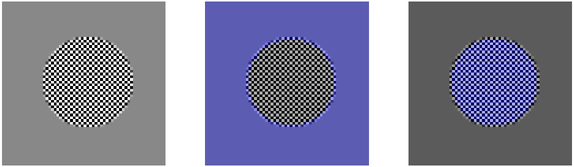
$$A_{ij} = \begin{cases} e^{-\alpha \left| I_i^{[1]} - I_j^{[1]} \right|} & \text{if i, j are neighbors} \\ 0 & \text{else} \end{cases}$$

- 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.



Results: Texture Distinction

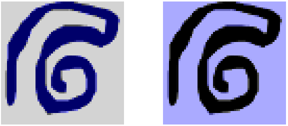
- Initially, weights in the coupling matrix A are based on the average intensity of the block
- The authors' algorithm scales the weights according to the similarities between two blocks' multilevel variance.
- This scaling makes it more likely for adjacent blocks with similar textures to be grouped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



Results: Scale Invariant Saliency Measure

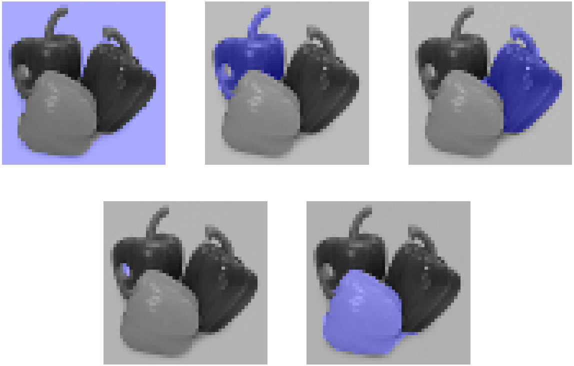
- The saliency measure $\Gamma_i^{[r]} = \dfrac{L_{ii}^{[r]}}{(1/2)W_{ii}^{[r]}}$ can be interpreted as the sum of the coupling coefficients along the border of block i divided by the sum of the coupling coefficients along connections internal to block i.
- Observe that this saliency measure is neither 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.

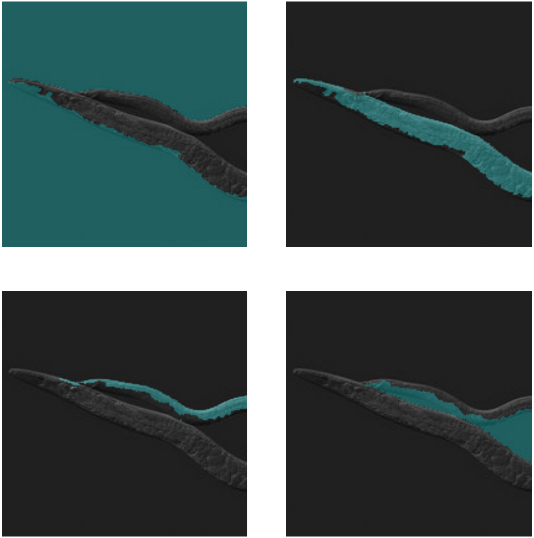


Segmentation with scale invariant saliency measure.

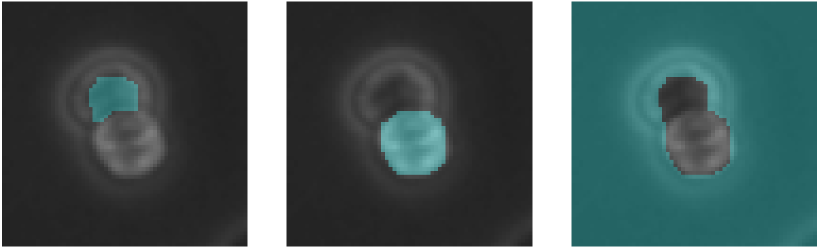
Results



C. Elegans.

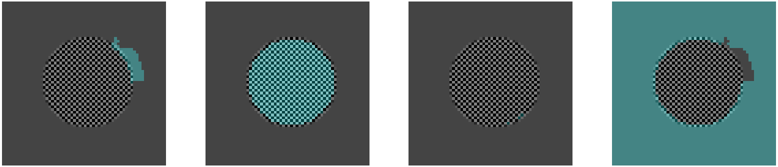


A pair of overlapping cells. It appears that one is on top of the other.

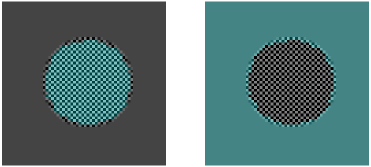


A few implementation details

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.



Inglis coarsener with maximum off-diagonal element strengths.

A few implementation details

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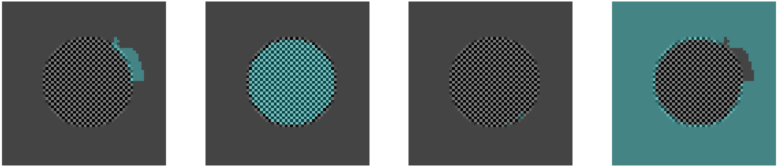
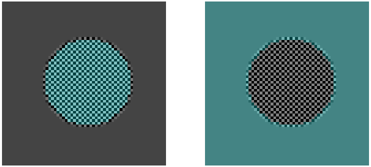
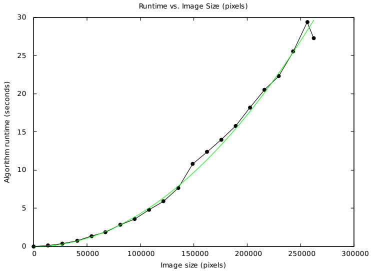


Inglis coarsener with off-diagonal row sum strengths.

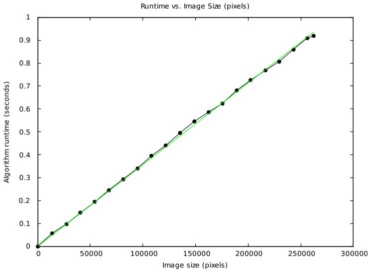


Ruge-Stüben coarsener with off-diagonal row sum strengths.

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!



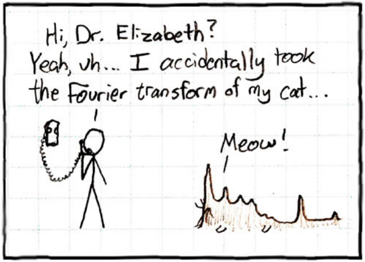
Inglis coarsening.



Ruge-Stüben coarsening.

Inglis et al., "Multilevel space-time aggregation for bright field cell microscopy segmentation and tracking", International Journal of Biomedical Imaging, (2010).

Questions?



Credit: xkcd.com, # 26