Hierarchical Partial Matching and Segmentation of Interacting Cells

Zheng Wu, Danna Gurari, Joyce Wong, Margrit Betke

BOSTON UNIVERSITY — COMPUTER SCIENCE

Motivation

Biology/Biomedical Engineering

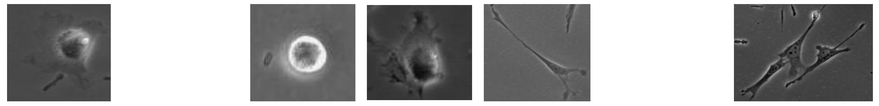
• *Model* the relationship between fibroblast cell behavior, cell morphology, and substrate stiffness

• *Bioengineer* small blood vessels

Computer Vision

• *Maintain shape recognition of cells* when they…

1. Have weak edges 2. Deform 3. Interact with other objects

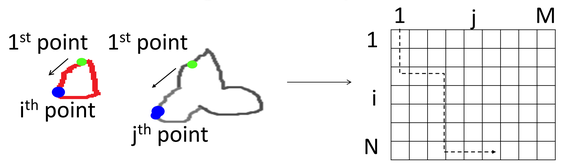


Key Method: Many-to-One Partial Curve Matching

Objective: Match every pixel on target curve (merged cells) to a pixel on one of the candidate curves (individual cells).

1. Dynamic Time Warping: Similarity Measure for Deformations

Compute similarity between segments on candidate and target curves; visualized as finding a shortest path in a DTW table.

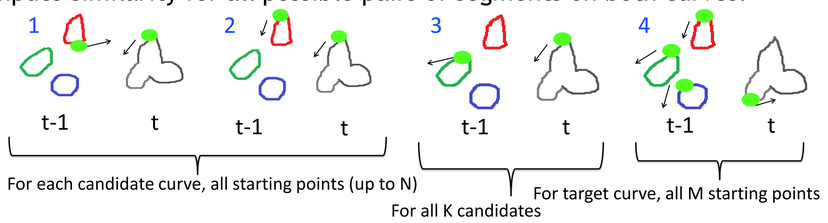


$$d_{i,j} = c_{i,j} + \min \begin{cases} d_{i-1,j} + w_i \\ d_{i,j-1} + w_j \\ d_{i-1,j-1} + w_{i,j} \end{cases}$$

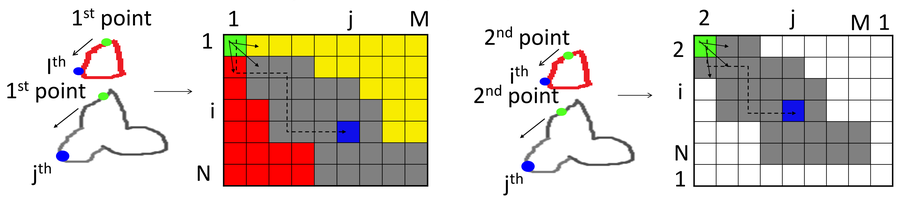
d_{ij} = dissimilarity cost; c_{ij} = matching cost between pair of points; w_i, w_j, w_{ij} = penalty terms

2. Double Cyclic Dynamic Time Warping (DCDTW)

Compute similarity for all possible pairs of segments on both curves.



To reduce computation by at least 1/3, reuse DTW table content

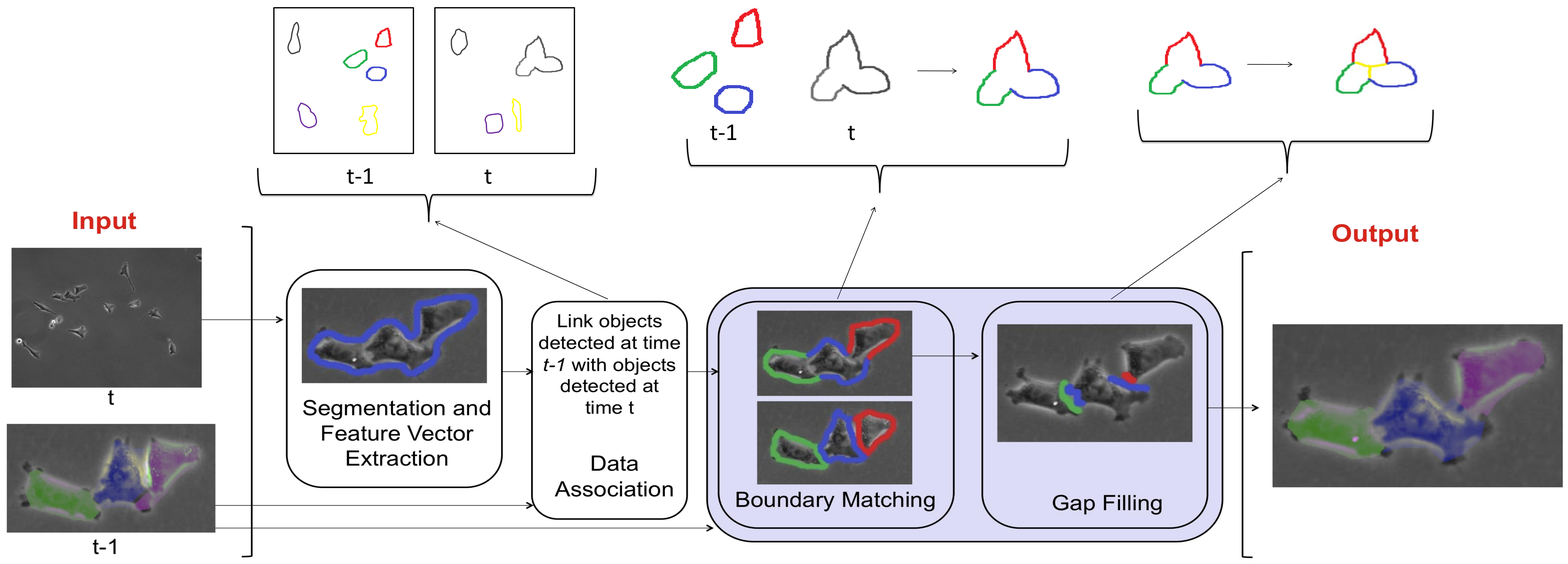


3. Hierarchical Partial Matching

Apply dynamic programming to optimally assemble fragments from candidates.

System Overview

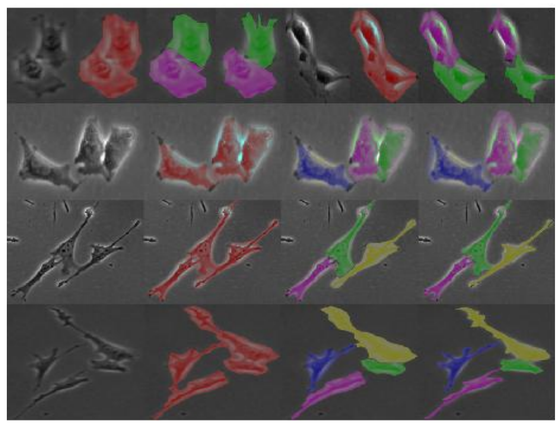
Key Contribution: A method to maintain shape recognition of cells and clutter as they undergo continuous deformation while touching each other for long durations.



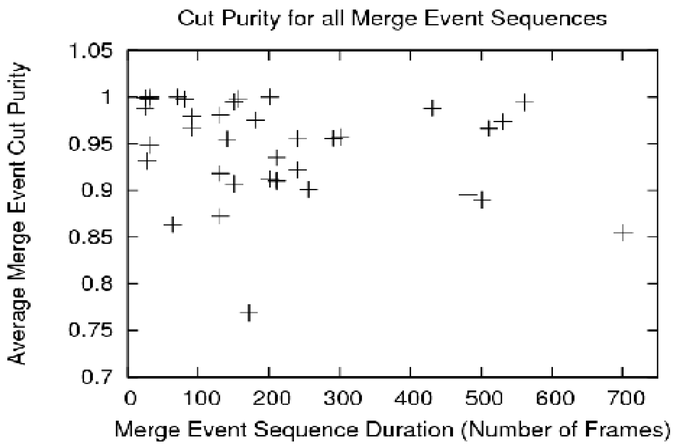
Experiments & Results

Datasets: *30* image sequences; *1,030x1,300* resolution; shows fibroblast cell population every *30* seconds for *16-24* hrs.

Merge Events Library: 41 subsequences containing 8068 images showing 1) cell-to-cell interactions, 2) cell-to-clutter interactions, and 3) apparent collisions due to under-segmentation.

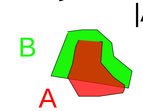


Original Image | Initial Segmentation | Final Output | Manual Segmentation

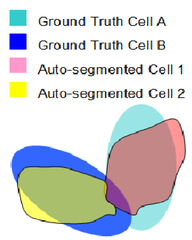


Quantitative Measure

$$\text{Accuracy} = \frac{|A \cap B|}{|A|}$$



Cut Purity = Avg Accuracy



Key Reference

R. Bise, K. Li, S. Eom, and T. Kanade. Reliably tracking partially overlapping neural stem cells in dic microscopy image sequences. In *MICCAI Workshop on OPTMHisE, 2009.*

Acknowledgements

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