Merging Cell Fragments in Oversegmented Corneal Endothelium Images

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Footnotes

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Abstract

Purpose : Biomarkers to assess the corneal endothelium, such as cell density, polymegathism and pleomorphism, are all derived from a segmentation of the endothelial cells. The large variation in cell size makes such segmentation difficult, causing either over- or undersegmentation. We evaluate a framework to combine cell fragments produced by oversegmentation of endothelial cells.

Methods : Five specular microscopy images (Topcon SP-1P) were captured six months post-op from five patients (ages 57-68) who had DSAEK (Descemet Stripping Automated Endothelial Keratoplasty) surgery in 2014-2015. The endothelium images were annotated by an expert to create the ground truth.
A stochastic watershed method (Selig et al., BMC Medical Imaging 15:13, 2015) was employed to generate superpixels, initializing the algorithm with a cell density of 6.000 cells/mm^2 to create an oversegmented image.
For each superpixel and for each combination of two adjacent superpixels, area (size) and circularity (shape) features were extracted. By using such features in a 2D Gaussian multivariate model, the probability of being a cell was inferred for each case. If two combined superpixels had a higher probability than both independent superpixels, the merge was established (fig. 1).

Results : The results from the merging algorithm were visually compared with the ground truth. The number of over- and undersegmented cells before and after the merging process were counted manually. The results are summarized in Table 1.
In total, the number of oversegmented cells were reduced by a total of 51.1 %, and 98.8 % of merges were correct. Thus, barely any undersegmented cell was created.

Conclusions : The pair-wise merging technique can reduce the number of oversegmented cells significantly by merely using two features. Considering multiple fragments simultaneously and including additional features might further reduce the amount of oversegmentation.

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		No. undersegmented cells		No. oversegmented cells	
	Number of cells	Pre-Merging	Post-merging	Pre-merging	Post-merging
Image 01	237	1	2	58	21 (-63.8 %)
Image 02	141	0	1	78	50 (-35.9 %)
Image 03	148	0	0	57	43 (-24.6 %)
Image 04	157	0	0	45	17 (-62.2 %)
Image 05	181	0	0	93	38 (-59.1 %)
Sum	864	1	3	331	169 (-51.1 %)

	Cell density (cells/mm^2)		
	Ground truth	Algorithm Estimation Error	
		Pre-merging	Post-merging
Image 01	2,095	+ 33.65 %	+ 15.61 %
Image 02	1,454	+ 77.99 %	+ 52.41 %
Image 03	1,496	+ 56.42 %	+ 31.89 %
Image 04	2,062	+ 39.52 %	+ 19.35 %
Image 05	1,641	+ 67.70 %	+ 33.64 %

Table 1. Results on the oversegmented corneal endothelium images in number of under- and oversegmented cells, and cell density estimation error with respect to the ground truth.

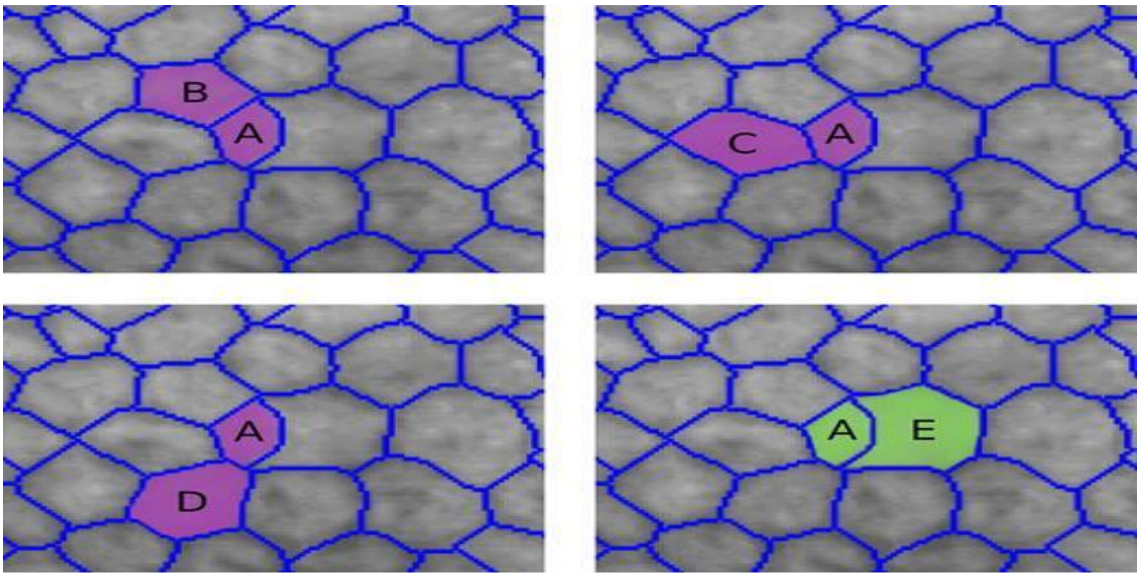

Figure 1. Representative example of the merging technique: Among all the combinations of A, A+E has a higher probability of being a cell (based on its area and circularity) than both A and E independently. No other combination generates a better probability. Thus, A and E are merged.

ARVO Annual Meeting Abstract | September 2016