Background and Literature Review

Image segmentation is the process of decomposing an image into multiple segments based on pixel similarity, edges or other prior information. It is essential for many computer vision tasks, including object recognition, detection and tracking. A hierarchical image segmentation is a set of image segmentations at different detail levels in which the segmentations at coarser detail levels can be produced from simple merges of regions from segmentations at finer detail levels. Therefore, the segmentations at finer levels are nested with respect to those at coarser levels.

Over the past few decades, hundreds or even thousands of segmentation algorithms have been proposed, trying to produce segmentation results that are similar to what human eyes perceive. However, image segmentation is still considered as a challenging problem due to the high dimensionality of visual data and complex nature of its content. Computing contour closures of an image provides a meaningful approach for image segmentation, which links together a set of fragmented contours into a cycle that separates an object from its background. It also leads to another complex problem: How to find the proper circles among intractable number of candidates existing in the contours.

Early researches identified a set of nonaccidental contour relations, such as classical Gestalt cues of parallelism and symmetry, that can be used to link together causally related contours. Yet the space of possible closures is still overwhelming, particularly when one allows larger boundary gaps in a closure. One possible taxonomy for categorizing related work is based on the nature of the prior information used to constrain the grouping process. Since it’s unclear how to make methods based on prior information scale up to large databases, our project focus on methods that make no assumptions about scene content and incorporate low-, mid-, high-level shape priors, as exemplified by Ren et al. [7]. One challenge faced by these merging shape priors methods is the complexity of pairwise contour grouping to detect symmetry-related contour pairs. At this point, Levinshtein et al. [16] proposed to overcome this computational complexity limitation by constraining the symmetric parts to be collections of superpixels.

Superpixels provide a convenient primitive from which to compute local image features. They capture redundancy in the image and greatly reduce the complexity of subsequent image processing tasks. They have proved increasingly useful for applications such as depth estimation, image segmentation, skeletonization, body model estimation and object location. For superpixels to be useful they must be fast, easy to use and produce high quality segmentations. Some of the outstanding superpixel-generation methods involve SLIC, Ncuts and Turbo.

Our project draws on this idea of grouping superpixels by three methods above but focuses on the more generic cue of closure. Further down the spectrum of prior knowledge are methods based on weaker shape priors than parallelism and symmetry. For example, Jacobs [17] uses convexity as well as gap to extract closed contours by grouping straight line segments. A less restrictive measure is that of compactness, which can be attained by normalizing the gap by area. Finally, our project uses the most general methods proposed by Alex et al. [core] that compute closure using only weak shape priors, such as continuity and proximity. This method uses a notion of boundary gap, which is a measure of missing image edges along the closed contour.

Elder and Zucker [18] model the probability of a connection between two adjacent contour fragments, and find contour cycles using a shortest path algorithm. Wang et al. [19] optimize a measure of average gap using the ratio cut approach.

All the above methods suffer from the high complexity of choosing the right closure from a sea of contour fragments. To cope with this complexity, Alex’s method tried to minimize closure cost using ratio cuts. His manipulation of superpixels provides greater scope not only for gap computation, but also for incorporation of internal appearance-based affinity. His methods also provide a set of optimal solutions that capture closures at multiple scale, also give users an opportunity to choose the ideal one for building next layer of hierarchical structure.