**2.1 Background and Literature Review**

Image segmentation is the process of separating an image into multiple parts of interests. This process can also be regarded as grouping adjacent pixels based on their similarity, the edges in the image and some 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 level, which can be implemented by getting the finer segmentation at the beginning and merging smaller parts into larger parts to get coarser segmentation.

Over the past decades, a great number of algorithms have been proposed to get an appropriate segmentation of an image. The goal is to get segments of image that are as close as human perceive and understand. Obtaining the contour closure provides a reasonable method towards this issue. It runs by firstly getting the contours and then linking some contours together to get the closure, which at the same time, segments the area of interest. There are two key problems to solve for this idea: How to obtain the potential contours; How to link these contours together to form closures among so may candidates. Below we will discuss in detail about the second problem.

To develop a strategy to combine contours together, researchers have found a set of nonaccidental contour relations, such as classical Gestalt cues of parallelism and symmetry. These relations have helped to reduce the selection space of composing closures, yet its computation complexity is still overwhelming. It’s especially true when we admit larger boundary gaps in a closure. Though we might be able to categorize the methods proposed by early researchers by the nature of prior information, the methods based on prior information is difficult to apply to large scale dataset. Hence, 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. [1]. There is still one challenge faced by these merging shape prior methods --- the complexity of pairwise contour grouping to detect symmetry-related contour pairs. At this point, Levinshtein et al. [2] took advantages of superpixels and made collections of them to overcome this computational complexity limitation.

Here we discuss in brief about superpixel. Traditionally, when we handle an image at pixel level, we are confronted with thousands of units, each of which provides certain information about the local area. In addition to computation complexity issue, dealing with one unit can hardly make any sense, because at least a group of them can be able to give some meanings. Superpixel can largely solve the above two problems, which can be thought as a bunch of pixels. At the superpixel level, we can handle an image with hundreds of units, with each one interpreting the local information very well. They have proved increasingly useful for applications such as depth estimation, image segmentation, skeletonization, body model estimation and object location. Considering the original intention of using superpixels, the approach for generating them must be efficient, 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.

With regard to shape information, early scientists also did much research. For example, Jacobs [3] made use of convexity as well as gap to extract closed contours. Comparatively speaking, normalizing the gap by area is a less restrictive measure. Taking advantage of probability theory, Elder and Zucker [4] tried to compute the probability of a link between two adjacent contour fragments, which are considered as weight between two vertices, and found contour cycles using a shortest path algorithm. Wang et al. [5] applied the ratio cut method to optimize a measure of average gap. However, 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 tried to minimize closure cost using ratio cuts [6]. The notion of boundary gap proposed in [6] is a measure of missing image edges along the closed contour. The manipulation of superpixels provides greater scope not only for gap computation, but also for incorporation of internal appearance-based affinity. It also provides a set of optimal solutions that capture closures at multiple scale, also gives users an opportunity to choose the ideal one for building next layer of hierarchical structure.