Real-World Pill Segmentation based on Superpixel Merge Using Region Adjacency Graph

Sudhir Sornapudi[1], R. Joe Stanley[1], Jason Hagerty [1,2] and William V. Stoecker[2]

[1]Missouri University of Science and Technology, Department of Electrical and Computer Engineering, Rolla, MO USA

[2]Stoecker & Associates, Rolla, MO USA

{ssbw5, stanleyj, jrh55c, wvs}@mst.edu

INTRODUCTION

- Misidentified or unidentified prescription pills may can lead to adverse drug events.
- A fast and reliable automated pill identification technique is essential to respond to this challenge.
- The goal of this study is to accurately segment consumer-quality pill images[1] captured using commonly available digital cameras and smartphones.
- Challenges: Varied backgrounds and shadows due to uneven lighting conditions

Consumer-quality pill images

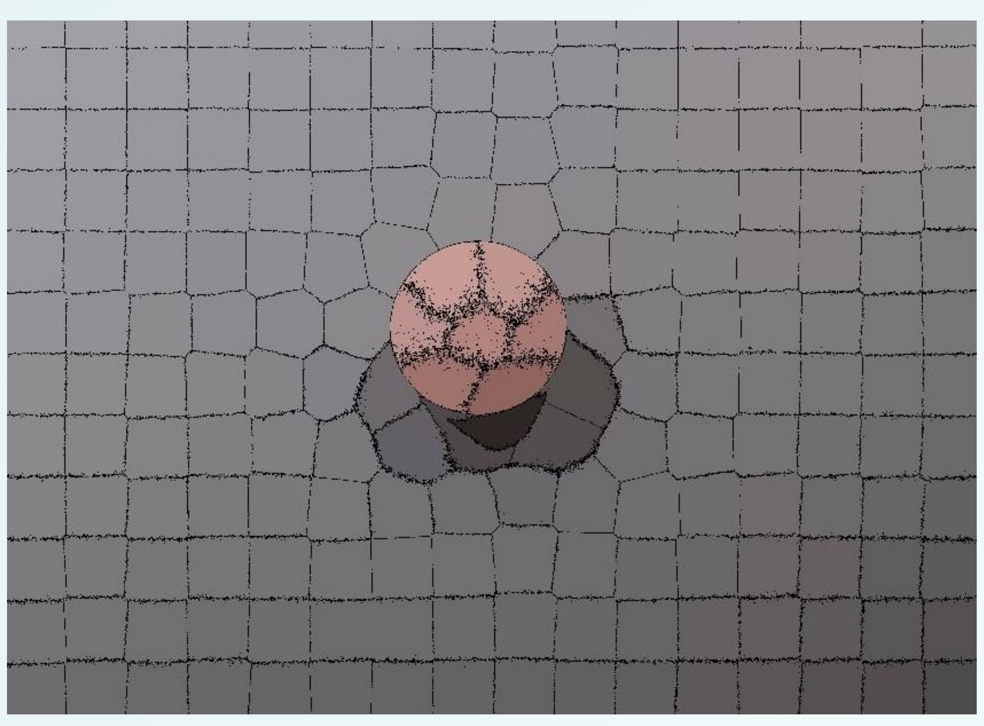
METHODS

Preprocessing

- The pill image is initially pre-processed using a Gaussian smoothing filter with standard deviation 2.

Superpixel Generation

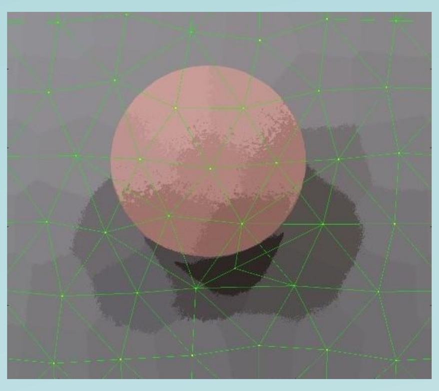
- This study uses the simple linear iterative clustering (SLIC) algorithm[2] to generate superpixels because it is faster, more memory efficient, and has better boundary adherence than its predecessors.
- The output is a labelled image, as the algorithm assigns a unique label for each superpixel region.
- An average color value of all pixels in a superpixel is calculated and assigned to the respective superpixel



Pill image over-segmented with superpixels

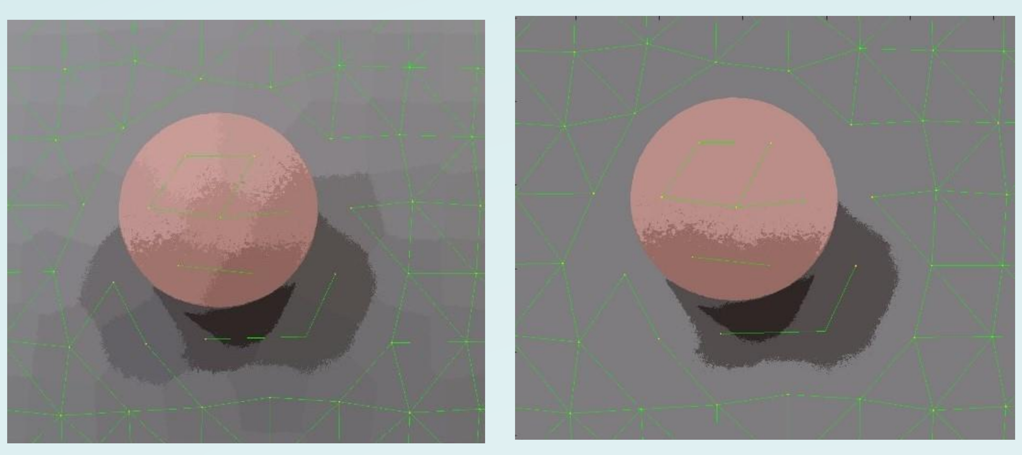
Region Adjacency Graph

- A region adjacency graph[3] is created as a step towards merging of superpixels.
- The over-segmented image is now considered as a graph. The centroid of each superpixel in the image is a node in the graph. All nodes in the adjacent regions are joined to form an edge



Labelled image (zoomed) with region adjacency graph

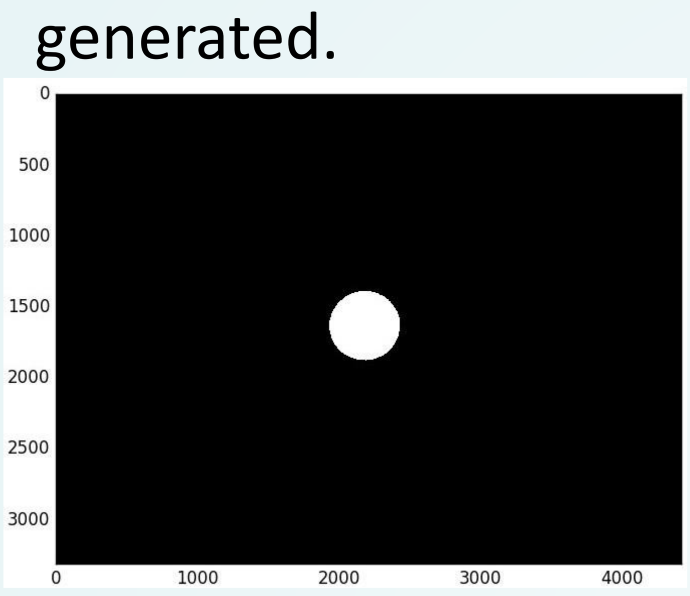
- The adjacent superpixel regions are merged if the edge weight is lower than the pre-determined threshold value; if the edge weight is higher than the threshold value, the graph is cut[4].
- The pixels of newly generated regions are assigned to the average color value of the merged regions. This reduces segmentation complexity substantially and results in easier generation of the pill mask.



(a)Superpixels with graph cut (zoomed),
(b) Merged regions with graph cut (zoomed)

Post-processing

- The resulting image is still affected by the shadows of the pill. The outer shadow needs to be merged with the background and the inner shadow shall be merged with the object.
- On analyzing the color intensity values of various pill images, the red and blue planes contribute the majority of intensity changes from pill to its shadow. A threshold is set and finally a binary mask is generated.



Binary Mask of the Pill

Pill Segmentation with bounding-box

RESULTS

- Out of 5000 consumer-quality masked pill images, results show accurate segmentation for 2243 pills. For 1862 pills, some shadow is included along with the pill in the mask. The remaining pill images (17.9%) have false segmentation.
- Limitation: Pills with color similar to background were partially or completely merged with the background, resulting in false segmentation.
- In summary, the proposed algorithm produces acceptable segmentation accuracy for 82.1% of 5000 consumer-quality pills.

Bounding-box of segmented Consumer-quality Pill Images (top) and Reference Pill Images (bottom)

- The quality of the binary mask produced from each of those images for varying scale factor ($i = 1.0, 0.9, 0.8, \dots, 0.1$) is given by

$$Q_i = \left(1 - \frac{|p_i - p_{1.0}|}{p_{1.0}}\right) * 100$$

Where p_i is number of pixels in the object region of binary mask and $p_{1.0}$ is the number of pixels in the object region of binary mask for a scale factor of 1.0.

Table 1: Effect of scaling factor on quality of binary mask and speed factor for individual pills

Scaling Factor	Speed Factor	Average Q value
1.0	1.00x	100%
0.9	1.11x	97.82%
0.8	1.66x	97.76%
0.7	1.95x	97.43%
0.6	2.93x	97.10%
0.5	4.12x	96.67%
0.4	**6.19x**	**98.46%**
0.3	10.30x	94.07%
0.2	19.08x	89.80%
0.1	40.30x	83.19%

Segmentation results with scale factor 1(left), 0.4(center), 0.1(right)

References

1. NLM, "National Library of Medicine : Pill Image Recognition Challenge." 2016.
2. R. Achanta, A. Shaji, and K. Smith, "SLIC Superpixels Compared to State-of-the-Art Superpixel Methods," *Pattern Anal. Mach. Intell.*, vol. 34, no. 11, pp. 2274–2281, 2012.
3. A. Tremeau and P. Colantoni, "Regions adjacency graph applied to color image segmentation," *IEEE Trans. Image Process.*, vol. 9, no. 4, pp. 735–744, 2000.
4. Y. Y. Boykov and M. P. Jolly, "Interactive graph cuts for optimal boundary amp; region segmentation of objects in N-D images," in *Computer Vision, 2001. ICCV 2001. Proceedings. Eighth IEEE International Conference on*, 2001, vol. 1, pp. 105–112 vol.1.