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EE 576 MACHINE VISION | HOMEWORK 3

Q1) The goal of this project is to find segments in an image and to get the feature representations of the resulting segments using SIFT. To achieve this, first, a connected component labeling algorithm is implemented to find proper segments in the given image. ConnectedComponentAlgorithm function (my own) implements this algorithm. The labeling is done with respect to the similarity of HSV values of two neighbor pixels x and x'. So, the L2-norm of the difference of the two pixels is compared with a threshold value in the labeling. Let's express the hue, saturation, and value channel values of the two pixels with H(x), S(x), V(x), H(x'), S(x'), V(x'). Then, the thresholding criteria can be expressed as:

$$dH = 2*\min(\mathrm{abs}(H(x)- H(x')), 180 - \mathrm{abs}(H(x)- H(x')))$$

$$dS = \mathrm{abs}(S(x)- S(x'))$$

$$dV = \mathrm{abs}(V(x)- V(x'))$$

$$\text{distance} = (dH * dH + dS * dS + dV * dV)^{1/2}$$

check: distance ≤ threshold or distance > threshold

Even though the algorithm works perfectly, the total number of different segments in each segmented image was too high. To solve this problem, I have implemented my own function called ReducedSegments. This function finds the total number of pixels/occurrences of a label in the segmented image first. Then, it sorts the occurrences of labels in the descending order. For a given parameter 'max_segment', it chooses the most 'max_segment' frequent labels as the main labels and sets other labels to zero. At the end, we get reduced segmented version of the image. For this project, I set max_segment to 10 and never changed it. For visualization, the original, segmented and reduced-segmented versions of the image "bot1_soic.jpg" are given below (with $\boldsymbol{\tau_h=25}$).

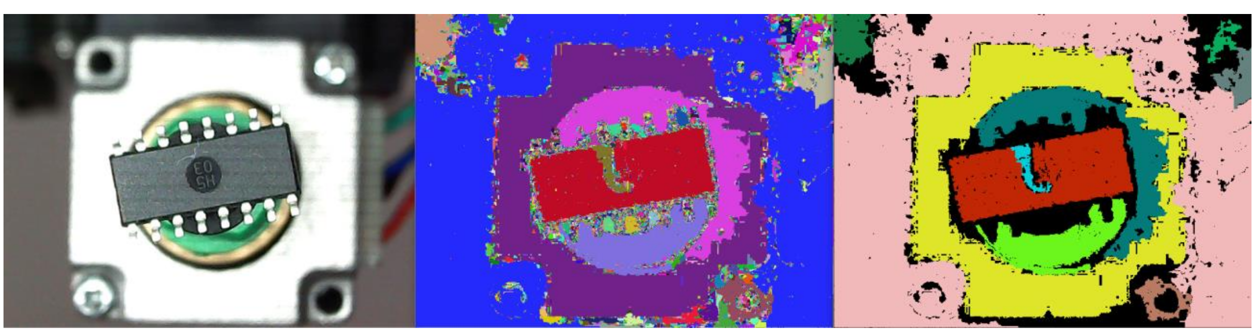

Fig1: The original, segmented and reduced-segmented versions of the image "bot1_soic.jpg".

Q2) To obtain the feature representations of each segment, I have implemented a function called SIFTextractSegment, which basically finds the SIFT features of the that segment and writes the list of keypoint locations and the associated 128-dimensional vectors to a text file.

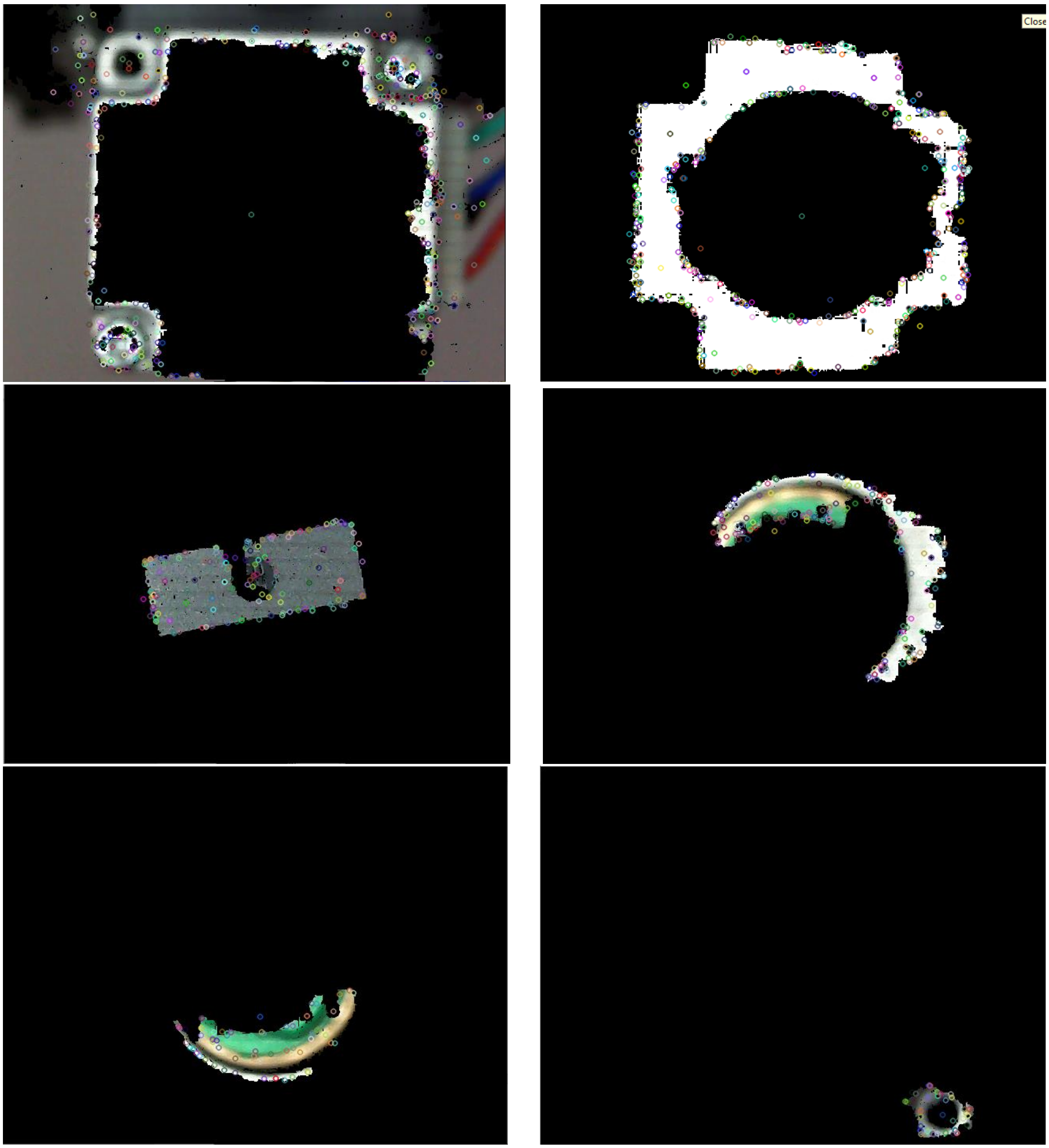

Fig2: The resulting Keypoints (found via SIFT) superimposed on the several respective segments (6 out of 10) of the image "bot1_soic.jpg".

Q3) In this part of the project, I have implemented a function called EllipseSegment, which determines the area, center and second order moments of a given segment and then draws an ellipse around each segment.

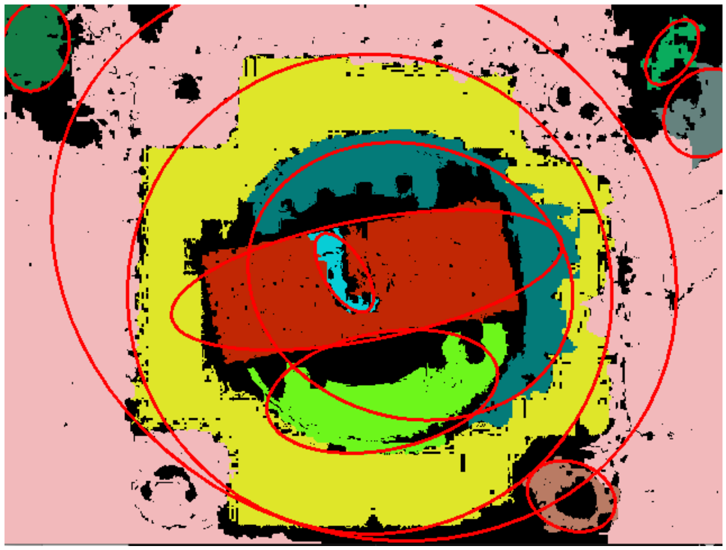

Fig3: Drawing ellipse around each segment of the image "bot1_soic.jpg".

Q4) In this part of the project, we will implement our algorithms on each image with 3 different threshold values, which varies from large to small. After this step, a table will be prepared that compares the number, mean area, mean shape coefficient and size variance of the segments found for each threshold values. The threshold values to be used are chosen as τ_h = 10, 25, 40.

	Number of Segments	**Number of Reduced Segments**	**Mean Area**	**Mean Shape Coefficient**	**Size Variance**	**Number of SIFT Key points**
τ_h=10	24837	10	2147.6	54.0464	2.7825e+06	300
τ_h=25	6417	10	6364.9	25.3495	1.30661e+08	498
τ_h=40	2376	10	7911.1	216.493	4.62118e+08	562

Table1: The table for the image "0.jpg".

	Number of Segments	**Number of Reduced Segments**	**Mean Area**	**Mean Shape Coefficient**	**Size Variance**	**Number of SIFT Key points**
τ_h=10	71776	10	11269.8	4.5829	2.36619e+08	775
τ_h=25	19867	10	23881	3.76289	1.13808e+09	857
τ_h=40	7396	10	27605.8	23.2971	6.22047e+09	1025

Table2: The table for the image "scene1.jpg".

	Number of Segments	**Number of Reduced Segments**	**Mean Area**	**Mean Shape Coefficient**	**Size Variance**	**Number of SIFT Key points**
τ_h=10	47015	10	8359.8	192.199	3.63511e+07	448
τ_h=25	5985	10	27236.3	5.8367	5.25231e+09	1087
τ_h=40	1820	10	29778.4	23.4822	7.61655e+09	438

Table3: The table for the image "bot1_1206_4a.jpg".

	Number of Segments	Number of Reduced Segments	Mean Area	Mean Shape Coefficient	Size Variance	Number of SIFT Key points
τ_h=10	63454	10	8318.2	51.4048	3.48173e+08	898
τ_h=25	12182	10	25428.5	23.1282	1.44456e+09	1395
τ_h=40	4609	10	28737.7	1065	2.42614e+09	1454

Table4: The table for the image "bot1_soic.jpg".

After this experiment, we can observe the effect of the threshold value on the segmentation task. If we set a smaller threshold value (in our case τ_h = 10), the total number of segments found after connected component labeling becomes too high. This is in fact not a desirable thing since excessive number of segments indicates that we could not protect the integrity of the real segments of the object that can be observed in the image and generated unnecessary/meaningless small segments. Due to these small segments, we can observe that for a lower threshold value, both the mean area and size variance of the segments are smaller compared to other two higher threshold values. On the other hand, if we set a higher threshold value (in our case τ_h = 40), the total number of segments found after connected component labeling becomes too low. This is also not a desirable thing since insufficient number of segments indicates that we could not find classify distinct parts of the object as a segment and therefore generated big segments with very small ones. This causes a huge amount of information loss. As a result of choosing a high threshold, both the mean area and the size variance of the segments increase. Also, we could observe that the total number of SIFT Key points usually increases when we increase the threshold value. To conclude, we should avoid choosing either too small or too big threshold values for the performance of our segmentation algorithm. When the threshold value is set to 25 (our mid-value), for almost every image, the segmentation result is much better. In addition, we can observe that when τ_h=25, the mean shape coefficient is smaller which is also a desirable thing.

For More Examples

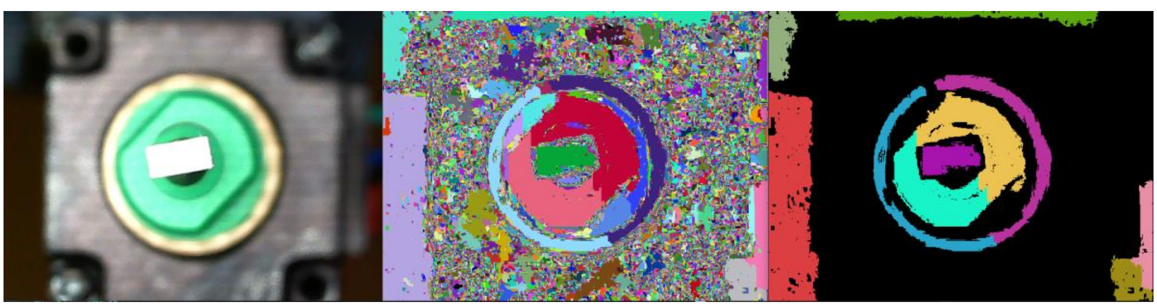

Fig4: The original, segmented and reduced-segmented versions of the image "bot1_1206_4a.jpg".

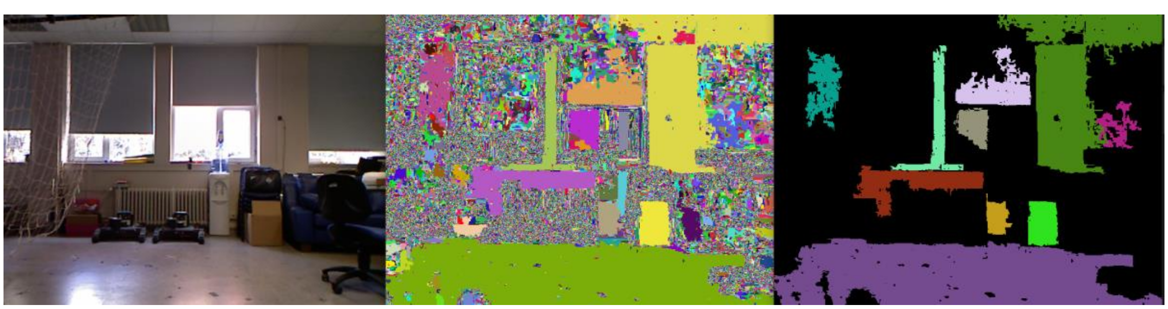

Fig5: The original, segmented and reduced-segmented versions of the image "scene1.jpg".