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Performance of Common Clustering Methods in Segmenting Vascular Pathologies in Capsule Endoscopy Images

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Introduction

In this article we compare *k*-means clustering [1] and mean shift [2], both with and without including spatial features, in their ability to segment areas of blood and angioectasia in images of the intestines obtained by capsule endoscopy. The aim of this study is to determine which clustering method and parameters are most effective in segmenting blood and angioectasia in such images, which are both recognizable by their red color. This can also be a useful pre-processing step in automatic detection of the presence of vascular pathologies in capsule endoscopy images. Classification algorithms to determine whether those images actually contain blood or angioectasia, and how to recognize which of the segments represents either pathology, are outside the scope of this article.

Method

We attempt to find optimal parameters for the clustering methods using 5-fold cross-validation on a training set of 302 images, each containing any vascular pathology, along with their corresponding annotated binary mask images. Those images as well as their annotations were obtained from a public database [3, 4]. The parameters we vary are the number of clusters for the *k*-means clustering methods *k* and the bandwidth *bw* for the mean shift clustering methods. The attempted values for *k* range from 2 to 9 with intervals of 1 and the values for *bw* range from 0.05 to 3.0 with intervals of 0.05. We perform the segmentation methods on all color space components of the original image in the RGB color space, as well as on their conversions to the color spaces *Lab*, YCbCr, HSV and CMYK. Additionally, we perform each method also including spatial features. We use a mask image to exclude the pixels that surround the image of interest.

To evaluate our segmentation in the cross-validation phase, for each image we create a binary image for each segment, of which we then measure the overlap with the binary image that represents the annotation of the pathological area using the Dice coefficient. The segment for which we achieve the highest Dice coefficient is then taken as the score of the image.

After this training phase, we perform the segmentation methods using the found parameters on two separate sets of capsule endoscopy images, one with the presence of bleeding and the other with the presence of angioectasia, to test the performance of the algorithms in segmenting the pathological areas in those images. Here we also extract and apply masks and perform the same evaluation as in the cross-validation phase, using the corresponding annotated images of those sets.

	k-means	Spatial *k*-means	Mean shift	Spatial mean shift
RGB	0.56	0.50	0.66	0.48
HSV	0.67	0.58	0.69	0.45
YCbCr	0.57	0.48	0.68	0.63
LAB	0.55	0.48	0.67	0.55
CMYK	0.55	0.55	0.65	0.38

Table 1: Average dice indices per color space for our test set of capsule endoscopy images of bleeding.

	k-means	Spatial *k*-means	Mean shift	Spatial mean shift
RGB	0.14	0.21	0.39	0.48
HSV	0.21	0.23	0.28	0.37
YCbCr	0.15	0.22	0.16	0.36
LAB	0.14	0.21	0.17	0.38
CMYK	0.21	0.20	0.50	0.44

Table 2: Average dice indices per color space for our test set of capsule endoscopy images of angioectasia.

Results

The values of *k* of the *k*-means and the spatial *k*-means algorithms we found to be optimal according to our measure were 9 for both in all attempted color spaces. The value found for *bw* of the mean shift and spatial mean shift algorithms was 0.05 in all cases. Using these found optimal values to segment our separate set of images with bleeding and angioectasia, we found the average Dice coefficients presented in table 1 and table 2. For all color spaces, we obtained the highest average Dice coefficient on our test set for mean shift; without spatial features for the bleeding set and with spatial features for the angioectasia set. Including spatial features improved performance in all cases except CMYK for the bleeding set, while it decreased performance in all color spaces for the angioectasia set.

Conclusion

We conclude that for the purpose of segmenting areas containing vascular pathologies in capsule endoscopy images, mean shift is superior to *k*-means. While on the bleeding set the inclusion of spatial features caused both methods to perform worse, on the angioectasia data set spatial mean shift performed significantly better than the original. For the bleeding set, there was no significant difference between color space for mean shift. For the set of angioectasia, best segmentation was achieved in RGB and CMYK. CMYK is thus a good choice for a color space for segmentation of general vascular pathologies, although it will computationally be more expensive than color spaces with lower dimensions. If the type of vascular pathology is limited to bleeding, the chosen method can make a more significant difference than the color space.

For further study, we suggest attempting higher values of *k* for the *k*-means algorithms and more values around 0.05 for the bandwidth of the mean spatial algorithms, since these values were at the edge of our range, while they werefound to be the optimal values in all cases. Additionally, we suggest considering other color spaces or focusing on specific channels of color spaces. We also note that our study was limited by the dependence on the low availability of preselected images and insufficiently accurate corresponding annotations in the public database we used. We therefore suggest the collection of custom labeled data and high quality annotations with the support of medical experts for future study.

References

[1] David Arthur and Sergei Vassilvitskii. k-means++: The advantages of careful seeding. In *Proceedings of the eighteenth annual ACM-SIAM symposium on Discrete algorithms*, pages 1027-1035. Society for Industrial and Applied Mathematics, 2007.

[2] Dorin Comaniciu and Peter Meer. Mean shift: A robust approach toward feature space analysis. *IEEE Trans. Pattern Anal. Mach. Intell.*, 24(5):603-619, May 2002.

[3] Koulaouzidis and D.K. Iakovidis. Kid: Koulaouzidis-iakovidis database for capsule endoscopy. http://is-innovation.eu/kid. [Online; accessed 10-01-2017].

[4] Iakovidis, D. K., & Koulaouzidis, A. (2015). Software for enhanced video capsule endoscopy: challenges for essential progress. *Nature Reviews Gastroenterology & Hepatology*, *12*(3), 172-186.