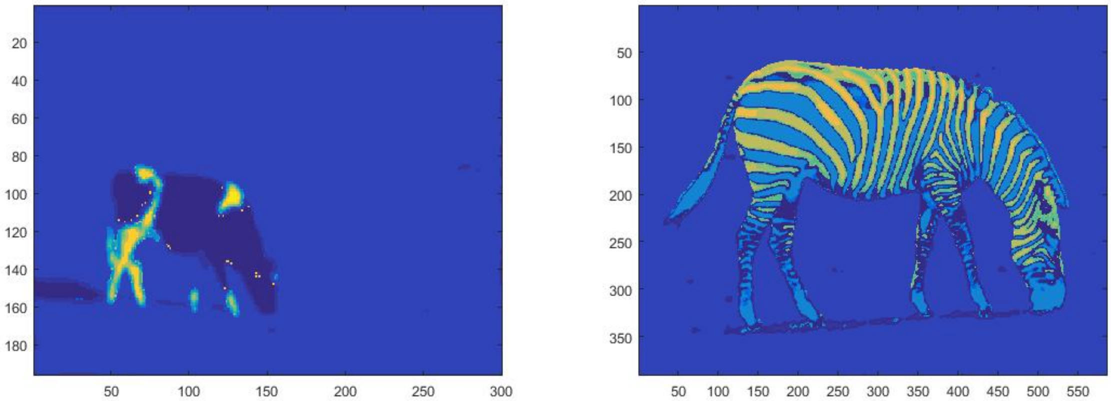
1 Segmentation

1.1 Image Preprocessing

It is better to do image segmentation in the L*a*b* color space since it better approximates human color perception. It allows for easier quantification of these visual differences since colors which to humans appear similar lie closer together in the L*a*b* color space. It is also useful since we can measure the difference between two colors by computing the euclidean distance.

1.2 Mean-Shift Segmentation

The Mean-Shift segmentation for the cow and zebra image results in a mediocre segmentation. This can be seen in Figure 1. For both images almost all background peaks lie close to each other resulting in a merge which is why the background of the segmented image has the same label with only a few exceptions. The animals themselves, however, are segmented poorly because of the contrast between the black and white fur patches, especially the white patches contain many different labels. This is because of shading, it gives the white fur a gray tone and since these lie further apart in the L*a*b* space than our threshold we do not merge them into one label.



(a) cow segmentation (b) zebra segmentation

Figure 1: cow and zebra image segmentation using Mean-Shift segmentation using $r = 0.03$.

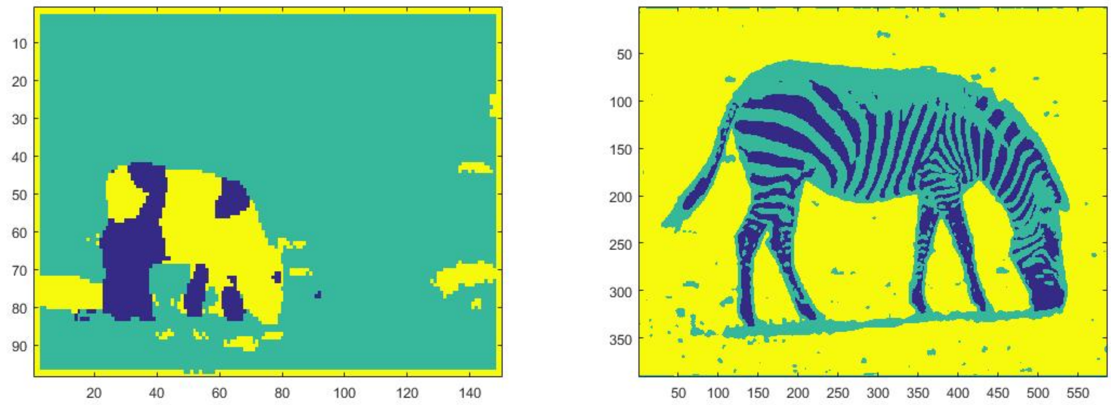
1.3 Expectation Maximization Segmentation

The Expectation Maximization has the advantage that we can manually define the number of clusters into which we want to segment the image. However, it is more susceptible to variations in color as a pixel can be labeled differently than its neighbours because of different intensities, placing it closer to another mean than the other neighbouring pixels and hence assigning it to another label. EM does not benefit from the strong spatial correlation of pixel neighbourhoods which is why a smoothed image is helpful. This drawback is due to the property of EM using gaussian mixture models which assumes the pixels were sampled i.i.d. which for images is not the case.

EM does not suffer from the gradient effect which we can observe in Figure 1 because we can predetermine the number of clusters. As can be seen in Figure 2, EM segments the image into three clusters, apart from some noise the three clusters are the background, black and white fur. Using more than three clusters we see the background clustering into different patches for the cow image and the fur shades clustering into different labels for the zebra image, this was to be expected since it is the next strongest variation in color after the three main colors.

In the following we list the Θ values for 4 and 5 cluster EM segmentation on the cow image:

For 4 clusters we obtain:



(a) cow segmentation (b) zebra segmentation

Figure 2: cow and zebra image segmentation using 3 clusters.

$$\alpha_{1..4} = \begin{bmatrix} 0.0437 \\ 0.3629 \\ 0.4739 \\ 0.1195 \end{bmatrix} \mu_{1..4} = \begin{bmatrix} 0.5091 & 0.4880 & 0.5546 \\ 0.3644 & 0.4491 & 0.5821 \\ 0.3369 & 0.4487 & 0.5868 \\ 0.1631 & 0.4821 & 0.5369 \end{bmatrix}^T$$

$$\Sigma_{1,2} = \begin{bmatrix} 0.0377 & 0.0015 & -0.0000 \\ 0.0015 & 0.0002 & -0.0002 \\ -0.0000 & -0.0002 & 0.0004 \end{bmatrix}, 10^{-3} * \begin{bmatrix} 0.2512 & 0.0032 & -0.0012 \\ 0.0032 & 0.0058 & -0.0004 \\ -0.0012 & -0.0004 & 0.0071 \end{bmatrix}$$

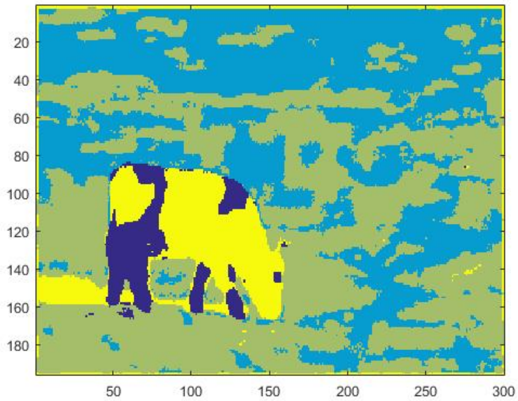
$$\Sigma_{3,4} = \begin{bmatrix} 0.0011 & -0.0000 & 0.0001 \\ -0.0000 & 0.0000 & -0.0000 \\ 0.0001 & -0.0000 & 0.0000 \end{bmatrix}, \begin{bmatrix} 0.0098 & -0.0019 & 0.0027 \\ -0.0019 & 0.0005 & -0.0006 \\ 0.0027 & -0.0006 & 0.0009 \end{bmatrix}$$

For 5 clusters we obtain:

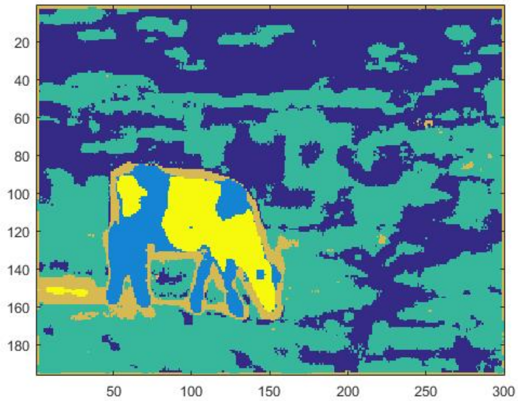
$$\alpha_{1..5} = \begin{bmatrix} 0.3681 \\ 0.0480 \\ 0.4540 \\ 0.0865 \\ 0.0435 \end{bmatrix} \mu_{1..5} = \begin{bmatrix} 0.3642 & 0.4492 & 0.5821 \\ 0.4455 & 0.4950 & 0.5434 \\ 0.3371 & 0.4483 & 0.5869 \\ 0.2617 & 0.4627 & 0.5668 \\ 0.0594 & 0.5044 & 0.5043 \end{bmatrix}^T$$

$$\Sigma_{1,2} = 10^{-3} * \begin{bmatrix} 0.2573 & 0.0024 & -0.0009 \\ 0.0024 & 0.0059 & -0.0003 \\ -0.0009 & -0.0003 & 0.0071 \end{bmatrix}, \begin{bmatrix} 0.0592 & -0.0000 & 0.0028 \\ -0.0000 & 0.0001 & -0.0001 \\ 0.0028 & -0.0001 & 0.0004 \end{bmatrix}$$

$$\Sigma_{3..5} = \begin{bmatrix} 0.0011 & -0.0000 & 0.0001 \\ -0.0000 & 0.0000 & -0.0000 \\ 0.0001 & -0.0000 & 0.0000 \end{bmatrix}, \begin{bmatrix} 0.0056 & -0.0004 & 0.0010 \\ -0.0004 & 0.0001 & -0.0001 \\ 0.0010 & -0.0001 & 0.0003 \end{bmatrix}, 10^{-3} * \begin{bmatrix} 0.2378 & 0.0467 & -0.0097 \\ 0.0467 & 0.0392 & -0.0145 \\ -0.0097 & -0.0145 & 0.0455 \end{bmatrix}$$

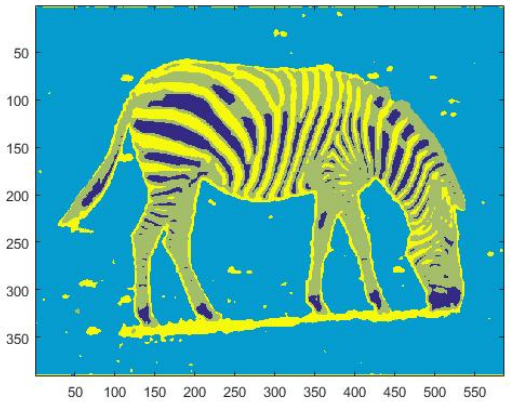


(a) 4 cluster segmentation

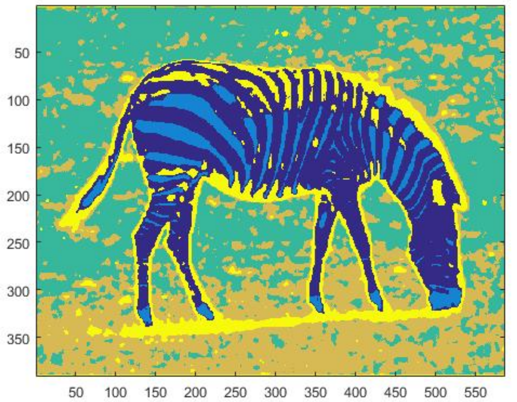


(b) 5 cluster segmentation

Figure 3: cow image segmentation using 4 and 5 clusters.



(a) 4 cluster segmentation



(b) 5 cluster segmentation

Figure 4: zebra image segmentation using 4 and 5 clusters.