8 Computer Vision – Pierre Beckmann

8.1 Image Preprocessing

Before segmenting the image is preprocessed. It gets smoothed using a 5x5 Gaussian filter with $\sigma = 0.5$. Then using matlab functions it is converted from RGB to L*a*b Space.

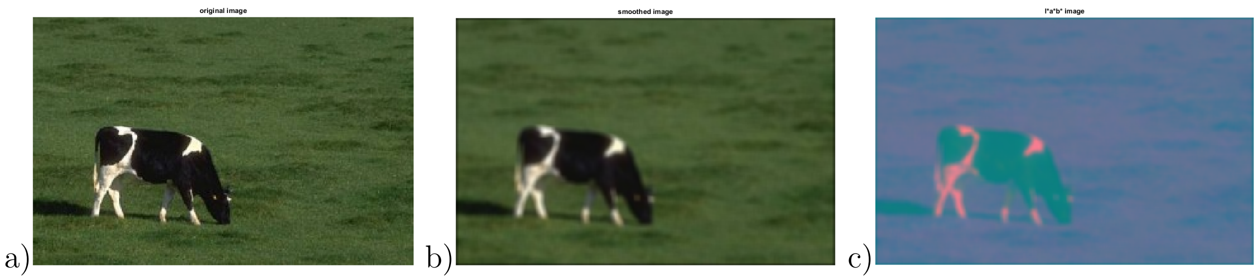


Figure 1: **Image Preprocessing** a) original image, b) smoothed image and c) L*a*b image.

In the L*a*b space pixels with the same colour but different shading will be nearer than in the RGB space. This is much more interesting for image segmentation. The white part on the cow's leg for example will be more likely to be put in the same cluster using the L*a*b space than the RGB space.

For the following segmentation algorithms the points were normalized using the function from a previous assignement `normalise3dpoints` and unnormalized after the computations.

8.2 Mean-Shift Segmentation

Now we organize the image into clusters using the mean shift algorithm: shifting a sphere of radius r to it's mean until convergence. This was done using 2 functions: `findpeak` that finds the mode (or peak) for a given pixel and `meanshift` that merges near peaks (distance lesser than $r/2$)and creates a map of appartenence for all the pixels of the image.

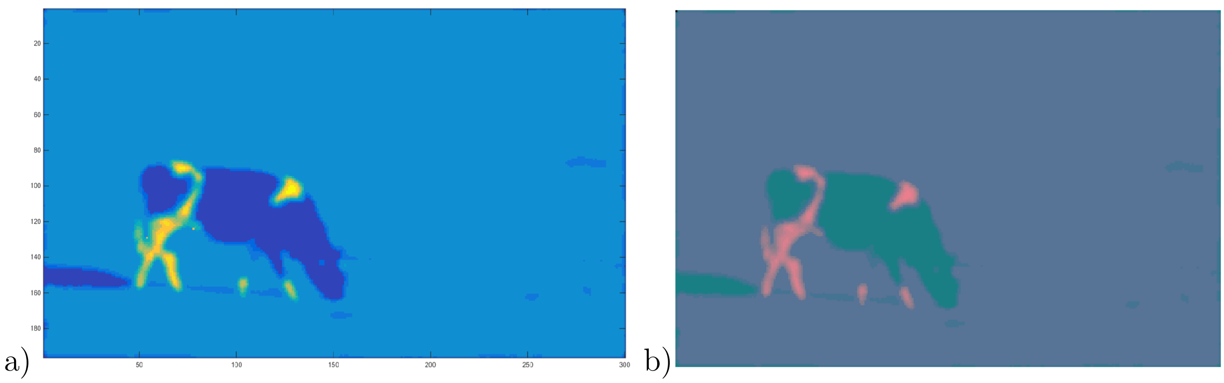
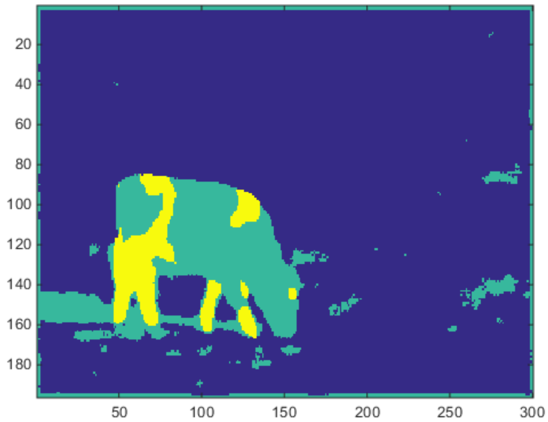


Figure 2: **Mean Shift Segmentation.** Implementation with a radius of 3 using normalized points of the L*a*b space. a) sgemneted image and b) reconstructed image using a.

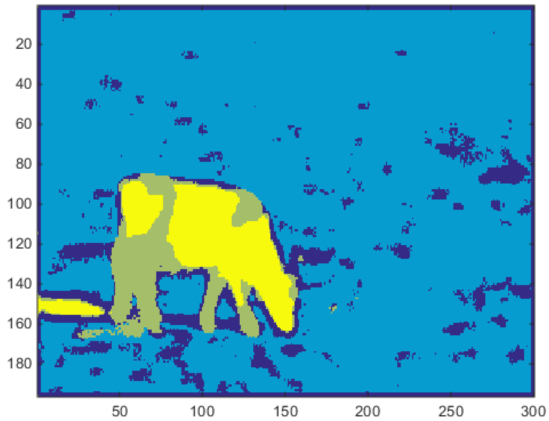
This segmentation separated the picture into 14 segments. The result is pretty good with the background almost only in one cluster and the colours of the cow clearly separated. However a part of one of the legs is lost in the background.

8.3 EM Segmentation

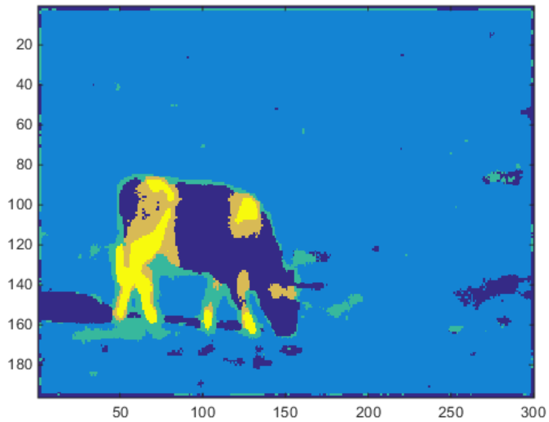
Next we implemented EM segmentation which separates the image into a given number of segments K. EM alternates between Expectation and Maximization steps until convergence. `Expectation` computes the probability of a being in a segment given the current guess a `maximization` computes the new guesses given the new probabilities. Here a guess describes the peaks of the clusters μ, the covariance matrices Σ and the weights α. Tolerences for converging were chosen empiricly.



a)



b)



c)

Figure 3: **EM Segmentation.** a) 3 segments, b) 4 segments and c) 5 segments.

Following results were obtained:
For $K = 3$

$$\mu_1 = \begin{bmatrix} 89.3311 \\ 114.4394 \\ 149.0918 \end{bmatrix} \mu_2 = \begin{bmatrix} 49.4438 \\ 121.4665 \\ 139.4818 \end{bmatrix} \mu_3 = \begin{bmatrix} 141.1582 \\ 125.5591 \\ 140.4582 \end{bmatrix}$$

$$\Sigma_1 = \begin{bmatrix} 0.7622 & 0.0013 & 0.0073 \\ 0.0013 & 0.0111 & -0.0023 \\ 0.0073 & -0.0023 & 0.0213 \end{bmatrix} \Sigma_2 = \begin{bmatrix} 10.5424 & -1.9122 & 3.0484 \\ -1.9122 & 0.4863 & -0.6553 \\ 3.0484 & -0.6553 & 1.0125 \end{bmatrix}$$

$$\Sigma_3 = \begin{bmatrix} 31.6837 & 0.7651 & 0.6701 \\ 0.7651 & 0.1361 & -0.0889 \\ 0.6701 & -0.0889 & 0.3467 \end{bmatrix}$$

$$\alpha = \begin{bmatrix} 0.8117 & 0.1527 & 0.0356 \end{bmatrix}$$

For $K = 4$:

$$\mu_1 = \begin{bmatrix} 78.5808 \\ 115.4814 \\ 147.9853 \end{bmatrix} \mu_2 = \begin{bmatrix} 89.7275 \\ 114.4122 \\ 149.0209 \end{bmatrix} \mu_3 = \begin{bmatrix} 116.7977 \\ 123.7949 \\ 141.5904 \end{bmatrix} \mu_4 = \begin{bmatrix} 19.6305 \\ 128.1852 \\ 129.8127 \end{bmatrix}$$

$$\Sigma_1 = \begin{bmatrix} 3.1847 & -0.2709 & 0.5432 \\ -0.2709 & 0.0590 & -0.0747 \\ 0.5432 & -0.0747 & 0.1503 \end{bmatrix} \Sigma_2 = \begin{bmatrix} 0.6754 & 0.0110 & -0.0033 \\ 0.0110 & 0.0102 & -0.0006 \\ -0.0033 & -0.0006 & 0.0182 \end{bmatrix}$$

$$\Sigma_3 = \begin{bmatrix} 40.0417 & 1.6159 & 0.1289 \\ 1.6159 & 0.2050 & -0.1638 \\ 0.1289 & -0.1638 & 0.4274 \end{bmatrix} \Sigma_4 = \begin{bmatrix} 1.4429 & -0.0030 & 0.2409 \\ -0.0030 & 0.0651 & -0.0439 \\ 0.2409 & -0.0439 & 0.1154 \end{bmatrix}$$

$$\alpha = \begin{bmatrix} 0.1782 & 0.7101 & 0.0533 & 0.0585 \end{bmatrix}$$

For $K = 5$:

$$\mu_1 = \begin{bmatrix} 42.0544 \\ 121.5194 \\ 138.0533 \end{bmatrix} \mu_2 = \begin{bmatrix} 89.5622 \\ 114.4372 \\ 149.0982 \end{bmatrix} \mu_3 = \begin{bmatrix} 81.6744 \\ 117.7979 \\ 146.9445 \end{bmatrix} \mu_4 = \begin{bmatrix} 68.2510 \\ 128.1831 \\ 134.1095 \end{bmatrix} \mu_5 = \begin{bmatrix} 178.7563 \\ 127.0330 \\ 141.4296 \end{bmatrix}$$

$$\Sigma_1 = \begin{bmatrix} 8.6716 & -1.9683 & 2.7776 \\ -1.9683 & 0.5180 & -0.6906 \\ 2.7776 & -0.6906 & 0.9733 \end{bmatrix} \Sigma_2 = \begin{bmatrix} 0.7172 & 0.0001 & 0.0075 \\ 0.0001 & 0.0105 & -0.0023 \\ 0.0075 & -0.0023 & 0.0211 \end{bmatrix}$$

$$\Sigma_3 = \begin{bmatrix} 2.4941 & 0.1764 & 0.0846 \\ 0.1764 & 0.0846 & -0.0764 \\ 0.0846 & -0.0764 & 0.2297 \end{bmatrix} \Sigma_4 = \begin{bmatrix} 29.0982 & -1.3419 & 2.0191 \\ -1.3419 & 0.1105 & -0.1441 \\ 2.0191 & -0.1441 & 0.2656 \end{bmatrix}$$

$$\Sigma_5 = \begin{bmatrix} 15.2006 & 0.1302 & -0.1166 \\ 0.1302 & 0.0527 & -0.0342 \\ -0.1166 & -0.0342 & 0.2730 \end{bmatrix}$$

$$\alpha = \begin{bmatrix} 0.1083 & 0.8005 & 0.0510 & 0.0228 & 0.0174 \end{bmatrix}$$

The covariance matrices Σ are in normalized space. The cluster peaks μ and weights α are unnormalized.

8.4 Zebra

The zebra also gives nice results using EM segmentation.

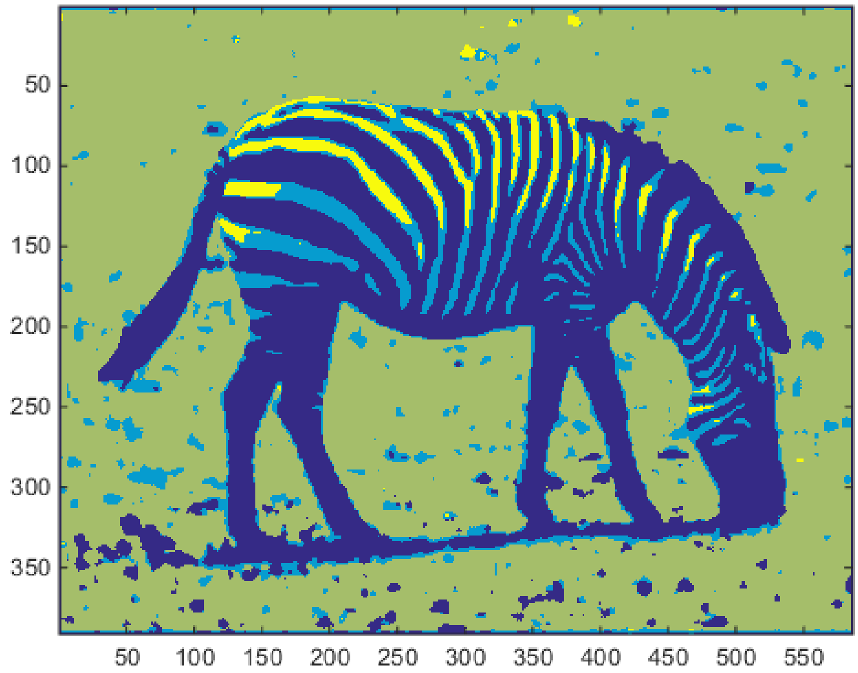


Figure 4: **EM Segmentation on the zebra image using 4 segments.**