Exercise 4, HT2020
Classification

Assignment in partial fulfilment of the requirements for the course

Computer-Assisted Image Analysis I

UPPSALA
UNIVERSITET

Master's Programme in Computer Science

Department of Information Technology

Authors:
Abraham Mathewos Meja
Marcello Pietro Vendruscolo
Shubhomoy Biswas

January 15, 2021

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1 Question 1

Are the two classes possible to separate by using either the x or y coordinate as a single feature? Explain why or why not.

The two classes can be separated by using either the x or y coordinate as a single feature. It is necessary, however, to explicitly emphasise that the achieved accuracy for the separation task is not as desirable (i.e., high) as it would be if more features were utilised to model the classifier, that is, the classes are not perfectly separated. Nevertheless, it seems that choosing the y coordinate ($y = 2$), as shown in Figure 1, yields a higher accuracy than the x coordinate.

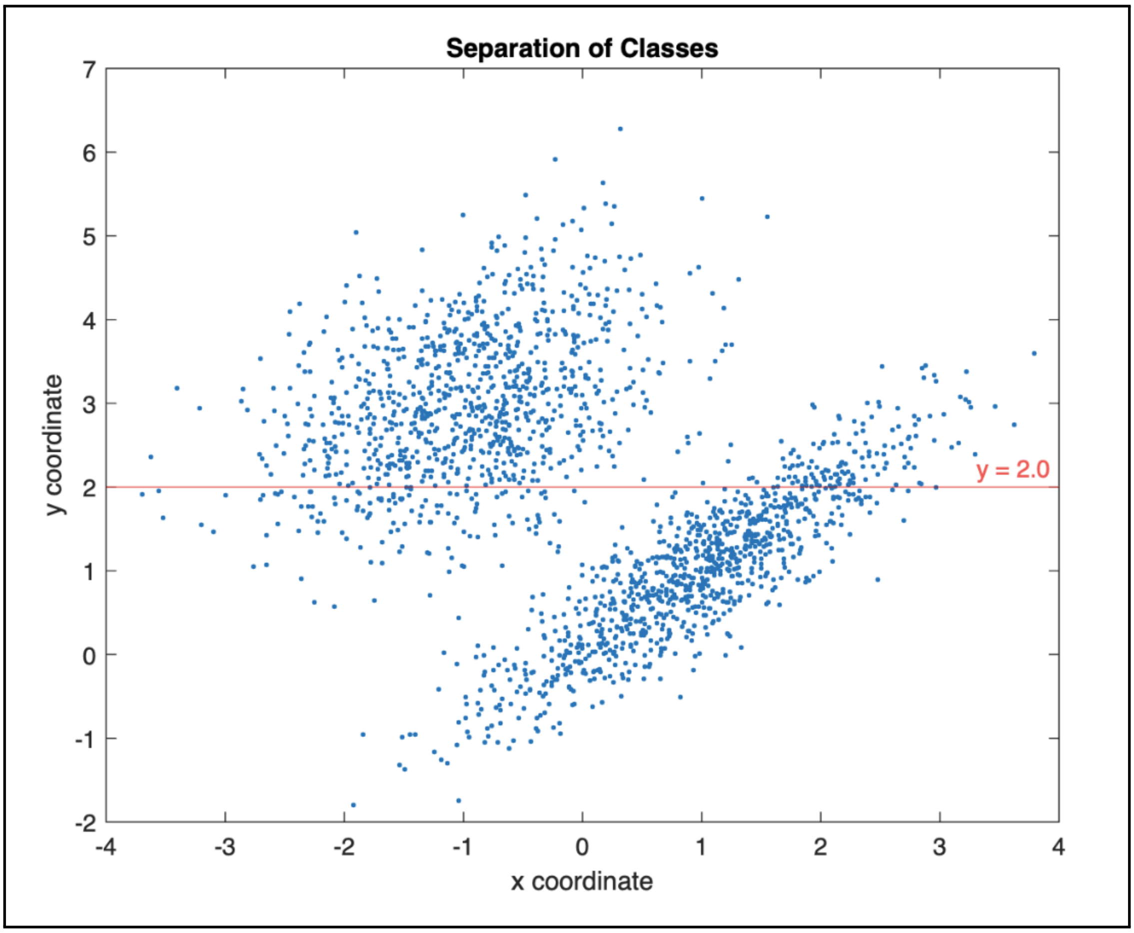


Figure 1: Separation of the two classes by a constant function $y = 2$.

2 Question 2

Does multiple thresholding give a successful classification of the three classes? Explain why or why not.

Taking into consideration the assumption that no preprocessing was allowed before multiple thresholding the image, the classification of background, hand and object was not successful. As shown in Figure 2, regions of the hand and of object have pixels sharing similar greylevel values to each another, which makes the complete separation a difficult, if not impossible, task. Furthermore, the background also contains some bright pixels with greylevel values similar to the foreground, which reduces the separation accuracy even further.

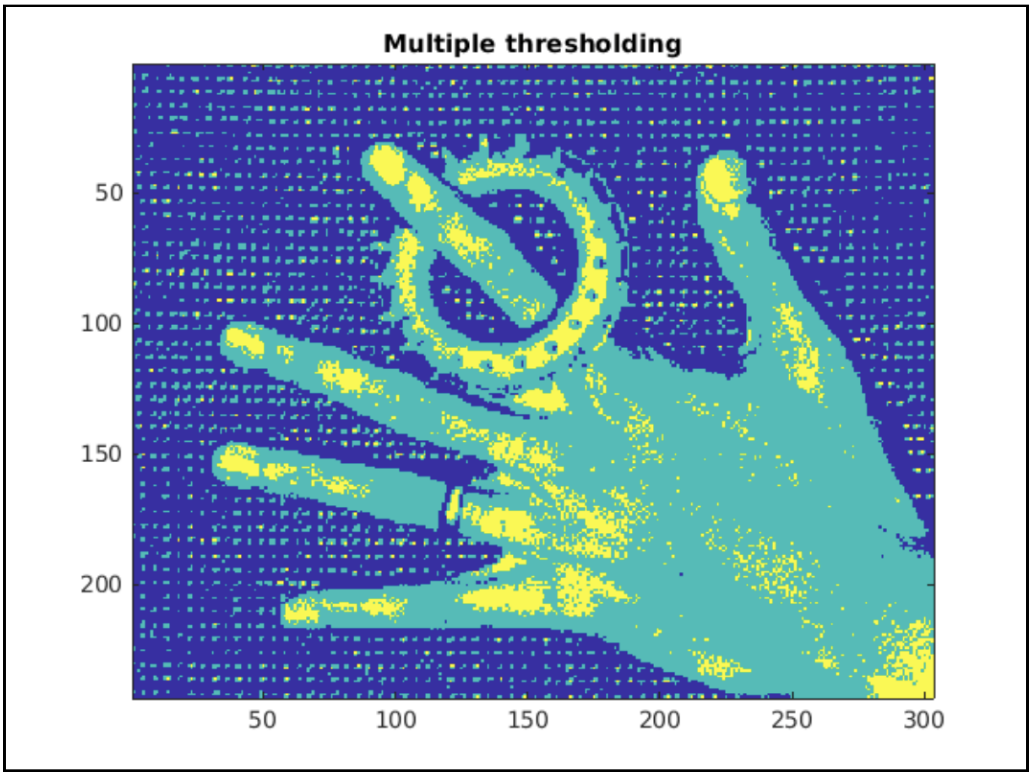


Figure 2: Multiple thresholding of image handBw at 110 and 175 threshold values.

3 Question 3

MATLAB*'s classify function uses Linear Discriminant Analysis (LDA) as default. What assumptions are made on the data by a linear classifier?*

MATLAB's *classify* function uses Linear Discriminant Analysis (LDA) by default. A linear classifier assumes that data is normally distributed. Moreover, it is assumes that the variance of each feature is approximatelly the same. In other words, to find a good predictor for a class y on any sample data, the sample data should have a similar distribution with the training data. In this particular question, the LDA classifier works well because the training and testing images are the same (i.e., the distribution of class's of pixels are same in the training as well as the testing image). In contrast to nonlinear classifier, such as Quadratic Discriminant Analysis (QDA), linear classifiers assume that classes can be separated by a line (or hyperplane in higher dimensions).

4 Question 4

Have the results improved using classification compared to thresholding? Is the classification more successful in the case with the grayscale image or single bands? Explain. Does it improve the classification to incorporate pairs of bands or the full RGB information? Discuss. Show your results from grayscale classification, one pair of features and full RGB classification.

Applying the classifier to the greyscale image did not produce significant classification improvements in comparison to the multiple thresholding implemented in Question 2, as it can be observed by comparing Figure 3 with Figure 2. As previously mentioned, the reason supporting this conclusion is that pixels in some regions of the hand as well as of the object share very similar greylevel values, which makes the perfect separation based only on this single greyscale channel a complex task.

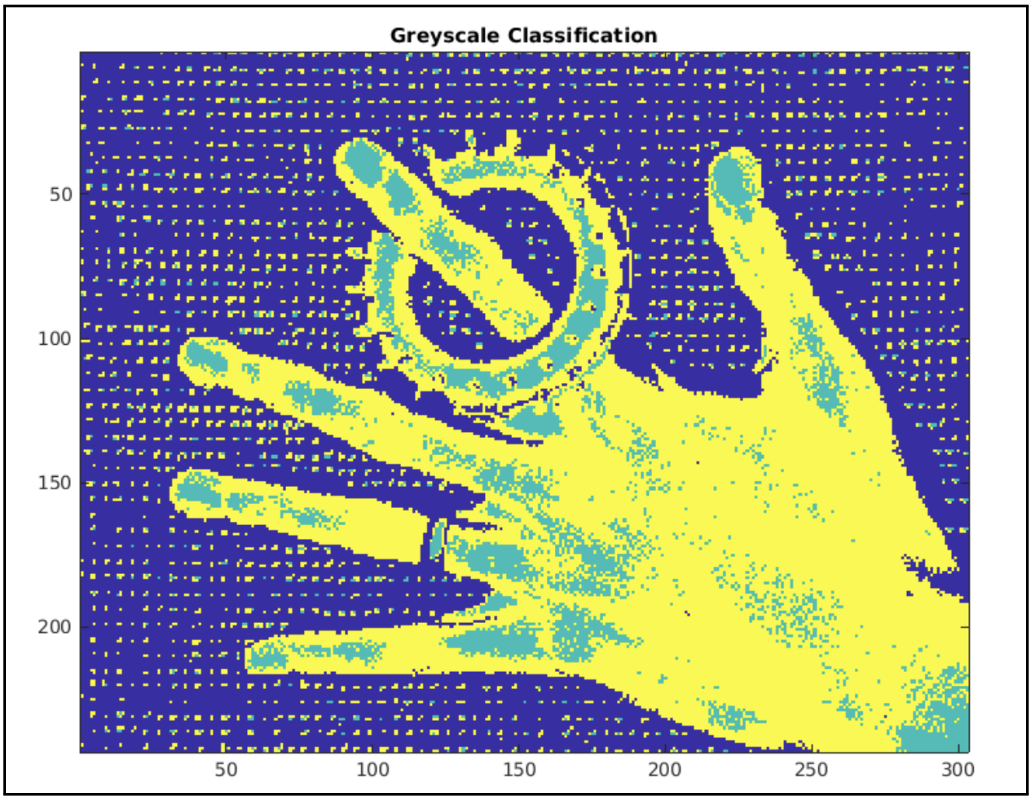


Figure 3: Classification applied to the greyscale image.

Nevertheless, the comparison of the results obtained when applying the classification to the greyscale image (Figure 3) as well as to the images created with single channels (i.e., red, green or blue shown in Figure 4) leads to the following observations:

- The classification is more successful in the case with the green single band image than with the grayscale image;
- The classification is less successful in the case with the blue single band image than with the grayscale image;
- To determine the classification success in the case with the red single band image in comparison to the grayscale image, it is required further information regarding the object of interest.

The explanation for such observations can be intuitionally derived from Figure 5. The greyscale image produced from the green channel of the RGB image displays adequate contrast between the background, hand and objects in terms of greylevel values which, consequently, yielded a better classification outcome. On the other hand, the greyscale image produced from the blue channel of the RGB image displays low contrast between the background and the hand in terms of greylevel values which, therefore, resulted in a worse classification outcome.

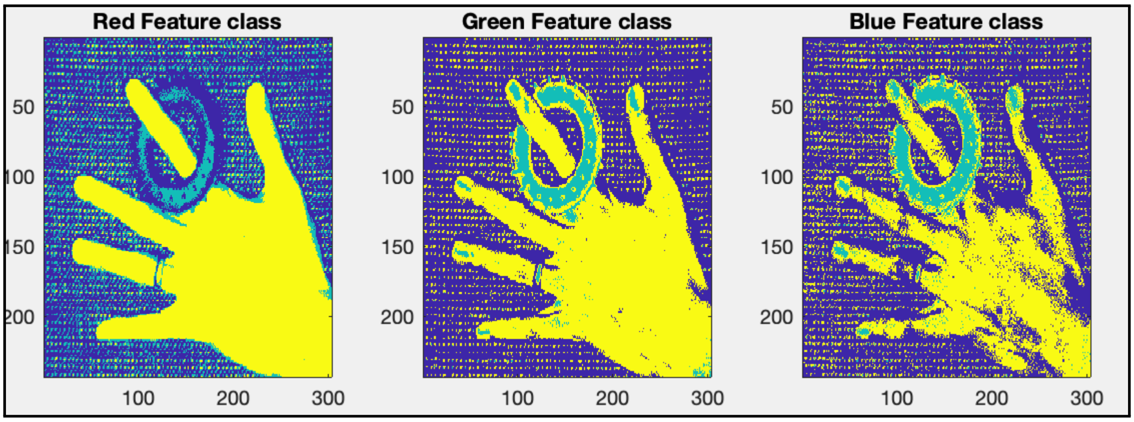


Figure 4: Classification applied to the greyscale images extracted from each channel of the colour image.

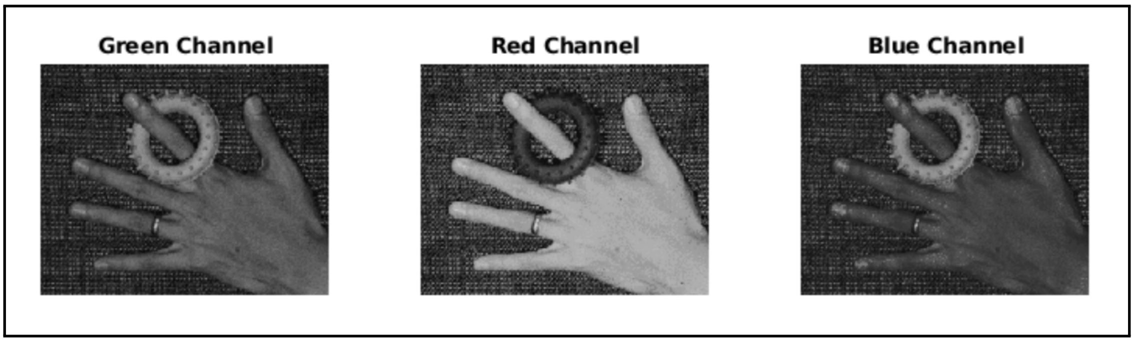


Figure 5: Greyscale images extracted from each channel of the colour image.

Advancing in the problem and incorporating pairs of bands or the full RGB information, more accurate classification can be performed, as shown by Figure 6 and Figure 7, respectively. The reason supporting this conclusion is that the combination of features creates distinguishably separable regions, as shown in Figure 8, resulting in training areas that do not contain data from multiple classes and, therefore, yielding a good classification. The combination of information from the three channels yielded the best classification outcome of all alternatives.

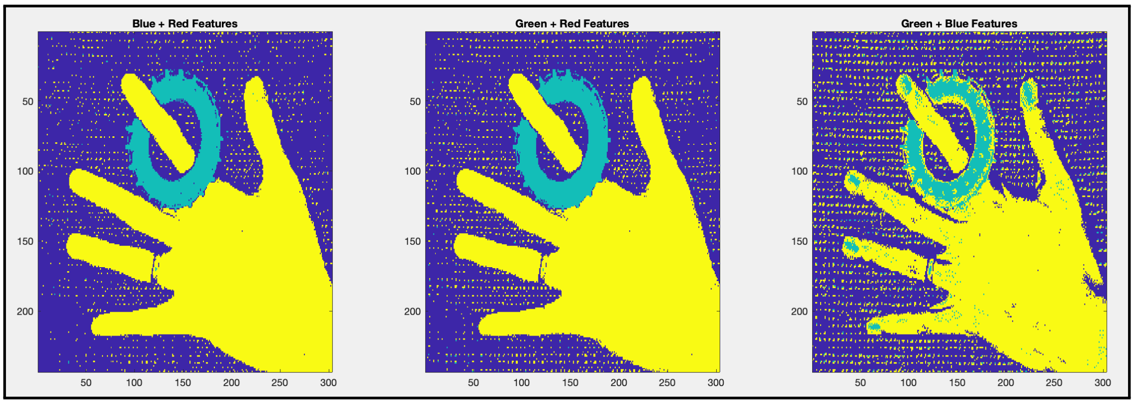


Figure 6: Classification applied to images created by the combination of pair of bands from the RGB image.

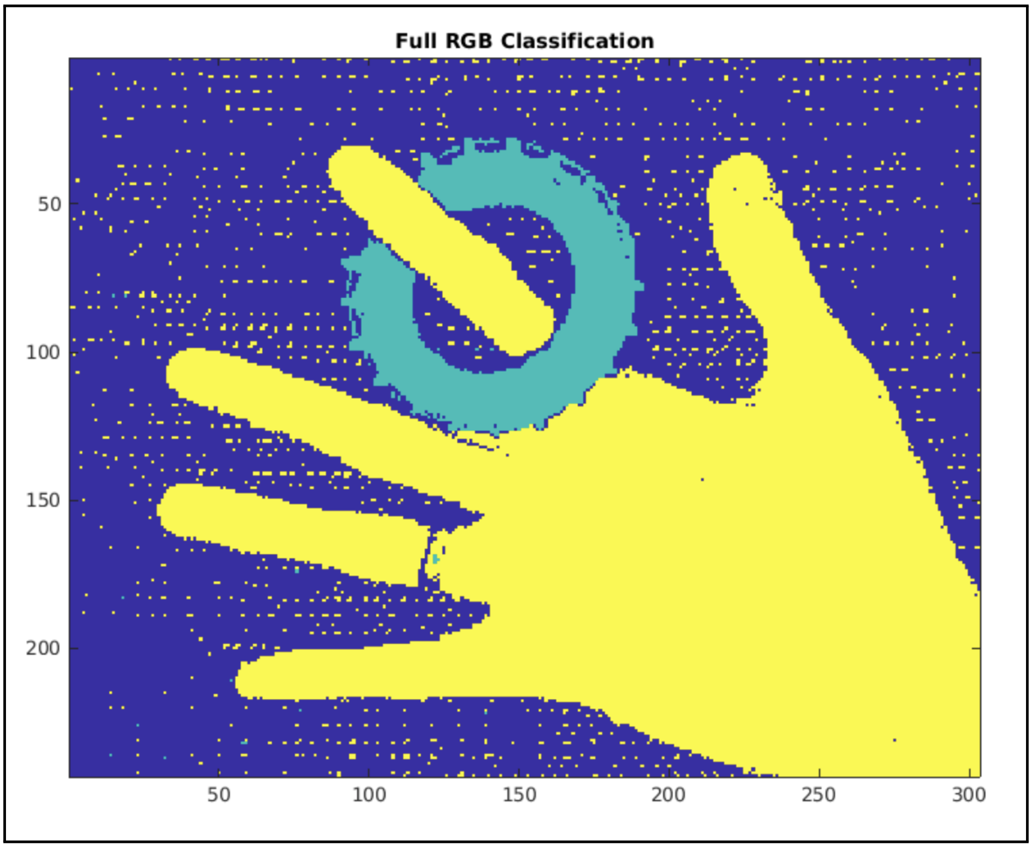


Figure 7: Classification applied to the RGB image.

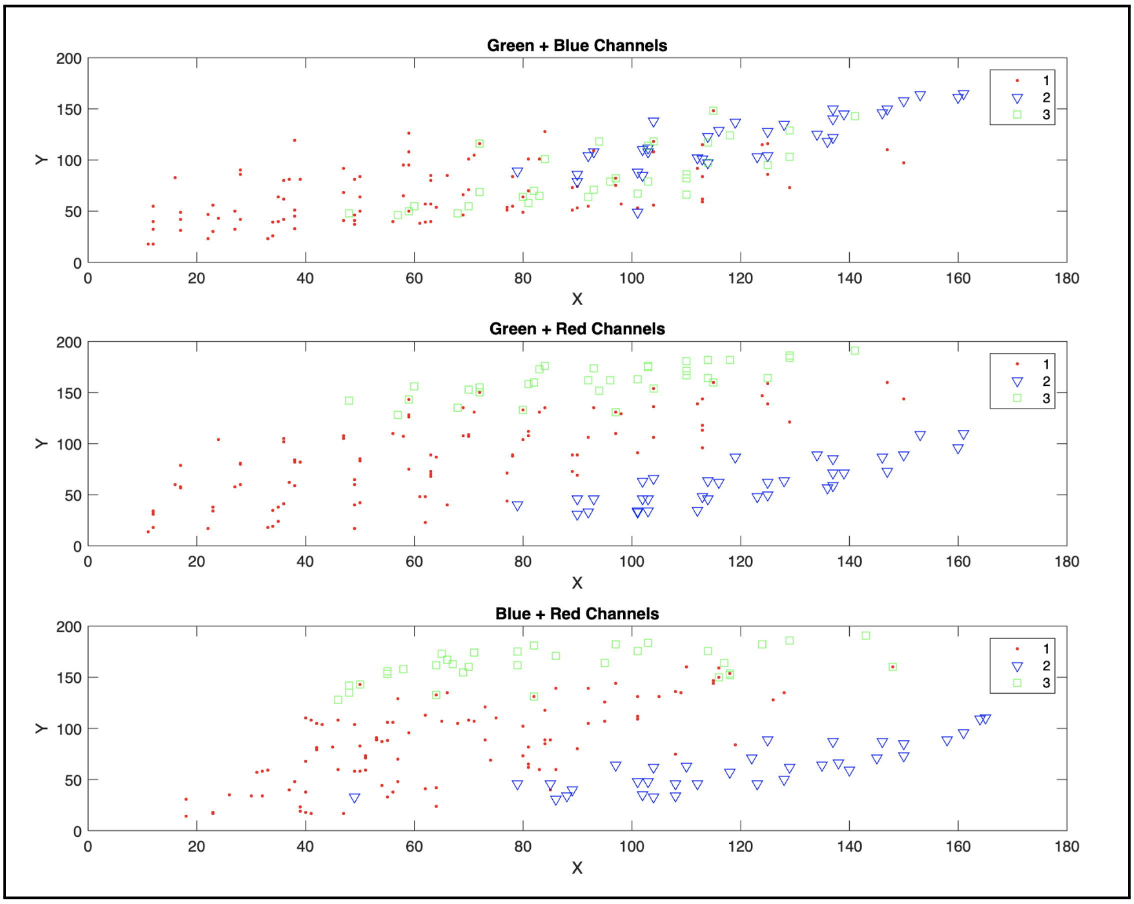
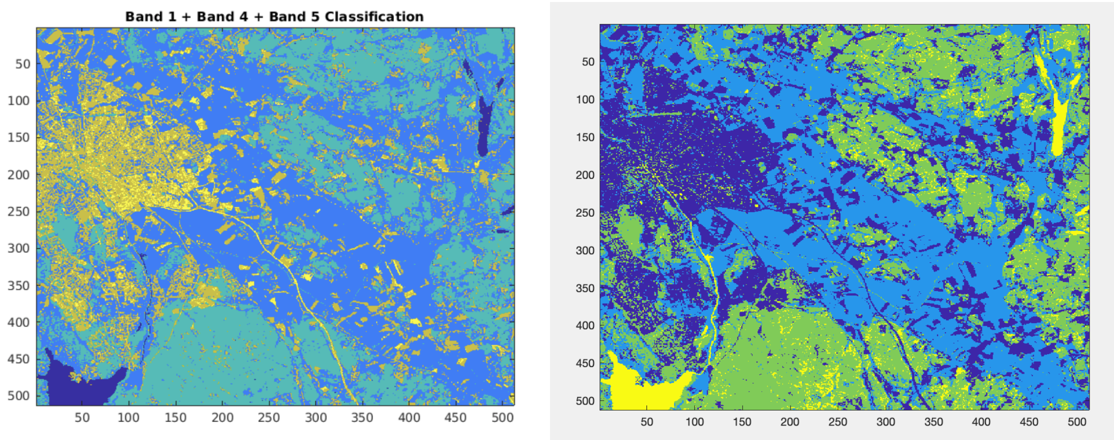


Figure 8: Scatterplots of the training feature vectors when combining pairs of bands.

5 Question 5

Which bands are you using for your classification? What classifier are you using? Which classes are possible to separate in a good way? Illustrate with images and scatterplots. Show images from your classification result and compare with classification using all bands. Discuss your results.

From the seven features available in the original image, bands 1, 4 and 5 were chosen for the classification purpose. Classifiers implementing both the Linear Discriminant Analysis and Quadratic Discriminant Analysis were utilised for comparison purpose. However, it was observed that the quality (i.e., classification accuracy) of the resultant images depended majorly on the training area chosen. The results of the classification are presented in Figure 9a and, as it can be observed, five classes were designated, namely water bodies, forest area, agricultural area, urban area and roads. The separation was not perfect. For example, there are classification mistakes on the water body in the top-right corner of Figure 9a and the water stream crossing the centrum of the city was not recognised properly. The reason for such mistakes can be that the designed training areas contain data from multiple classes for the combination of chosen bands, not providing enough separation of classes.



(a) QDA Classifier

(b) LDA Classifier

Figure 9: Classification using bands 1, 4 and 5.

Despite, when compared to classification using the full set of bands (illustrated in Figure 10), it can be observed that the overall classification result achieved a satisfactory level of accuracy, identifying the main areas where the classes are located.

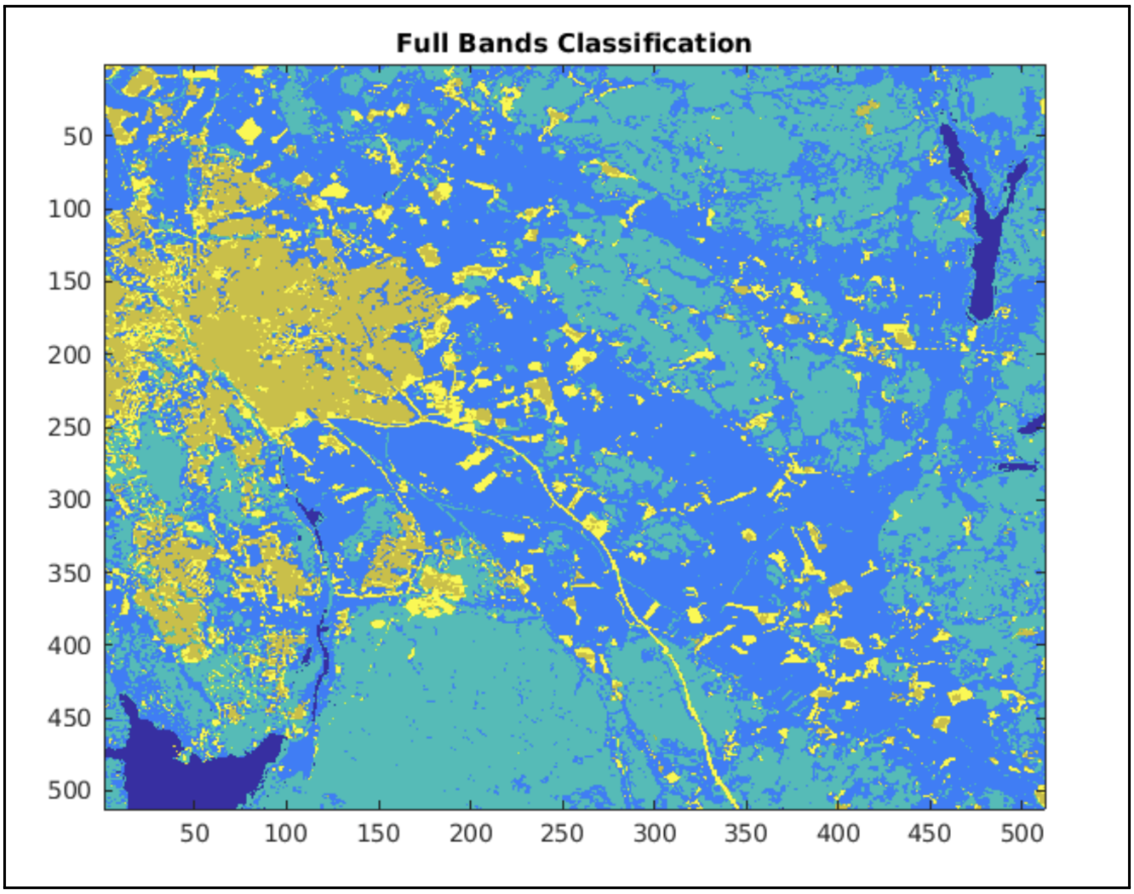


Figure 10: Classification using all seven bands.

6 Question 6

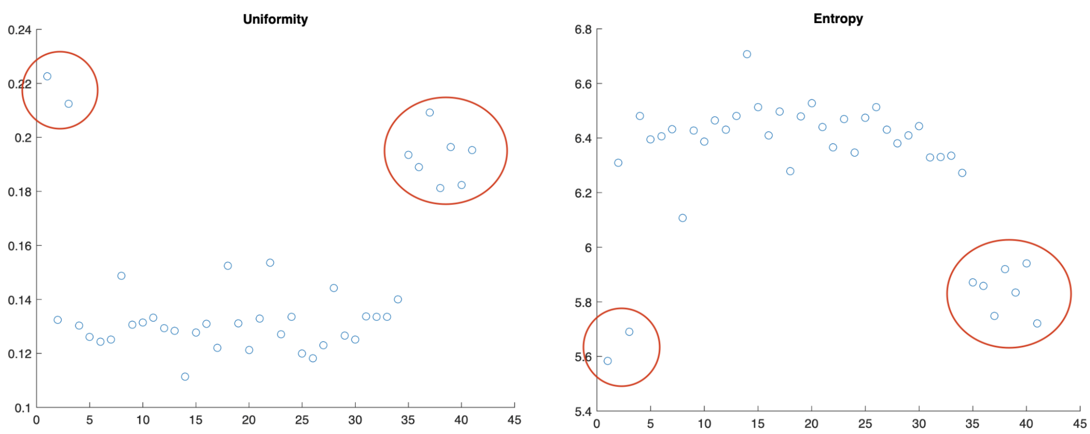
Is there any reason not to include all bands if they are not needed to separate the classes?

When considering classical classification approaches (i.e., not using neural networks), feature selection can be a decisive step to whether the outcome produced by the classification is desirable or not. Combining all features available and hoping that the classifier will perform well does not always work out. The combination of undesired features can hinder the identification of interesting relationships between other features by unnecessarily increasing the complexity of the model. In this particular case of a Landsat image with seven bands, each band provides more useful information for classification depending on the different parts of a landscape. The combination of all of them can obscure the valuable properties of a particular band. Furthermore, the inclusion of all features requires the additional use of resources, such as time or computational power, which should be reduced whenever possible.

7 Question 7

Which "offset" value did you use for the co-occurrence matrix? Plot uniformity and entropy for all the objects. You should have a plot similar to Figure 3. Using entropy and uniformity, say which objects are outliers and should be removed from the sequence. Why?

Different offset values were tried out for the co-occurence matrix, including [0 2], [1 2], [-2 5] and [-10 20] among others. Almost all of them yielded similar plots as shown in Figure 11b and Figure 11a. As it can be observed from the plots, objects 1, 3, 35, 36, 37, 38, 39, 40 and 41 can be removed from the sequence, as the uniformity and entropy co-relation for these objects are far off in comparison to the rest of the actual viruses recognised by the template virus. In other words, these outliers have different spacial information—texture, in this case—than the rest of the viruses.



(a) Uniformity (b) Entropy

Figure 11: Uniformity and Entropy plots of objects.