CS598 PS 2017 – PROBLEM SET 3

This problem set is due on October 20th. Submit your answers as a PDF document (no scanned handwritten pages) using compass. For each day that submission is late your problem set's grade will drop by 10%. Try to do the exercises in this problem set by yourself. Their purpose is to give you some experience so that you can have an easy time with your final project. You should jointly write the project proposal with your project partners. Make sure that all the partner names are mentioned in it. Make sure that all members of a team have the proposal in your submission.

PART 1 – IN THEORY

Problem 1. Discriminant functions

For the four following cases that involve two Gaussian distributed classes with the given means and covariances, find and plot the discriminant function that optimally separates them. Make sure that you plot the two class Gaussians as well.

a)
$$\mathbf{m}_1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \quad \mathbf{C}_1 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$
$$\mathbf{m}_2 = \begin{bmatrix} 4 \\ 0 \end{bmatrix} \quad \mathbf{C}_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

b)
$$\mathbf{m}_1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \quad \mathbf{C}_1 = \begin{bmatrix} 1 & 0 \\ 0 & 2 \end{bmatrix}$$
$$\mathbf{m}_2 = \begin{bmatrix} 4 \\ 3 \end{bmatrix} \quad \mathbf{C}_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

c)
$$\mathbf{m}_1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \quad \mathbf{C}_1 = \begin{bmatrix} 1 & 0 \\ 0 & 2 \end{bmatrix}$$
$$\mathbf{m}_2 = \begin{bmatrix} \frac{1}{2} \\ 0 \end{bmatrix} \quad \mathbf{C}_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

d)
$$\mathbf{m}_1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \quad \mathbf{C}_1 = \begin{bmatrix} 1 & 0 \\ 0 & 2 \end{bmatrix}$$
$$\mathbf{m}_2 = \begin{bmatrix} 4 \\ 0 \end{bmatrix} \quad \mathbf{C}_2 = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix}$$

PART II – IN PRACTICE

Problem 2. Handwritten digit recognition

In the problem set archive there is a file called `digits-labels.mat`. Just like in the previous problem set it contains a set of digit images and their corresponding labels.

Split the data so that you keep 100 training digits for each class and use the remaining data as testing samples. Using the training digits construct a classifier that performs PCA to reduce the dimensionality and learn a Gaussian for each digit class. Evaluate the predicted classification from the testing digits. How many dimensions do you have to use to ob-

tain performance in the 90% range? Make a note of any interesting behavior that you encounter while making your classifier.

Extra credit: Can you implement a different classification scheme that can achieve better performance? Can you do so while keeping fewer dimensions in the dimensionality reduction step? Feel free to use a different classifier, but also a different dimensionality reduction or preprocessing method.

This is a subset of the MNIST digit data that is a standard benchmark for classification tests. You can find the full data set and state of the art results in:

http://yann.lecun.com/exdb/mnist/

The data in the mat file is only the test set data from the original set. As before feel free to use freely available code, but you get extra credit for writing your own.

Problem 3. Speech / No Speech classifier

I hate DJs. They talk too much as opposed to playing music. One way to automatically deal with that is to construct a classifier that can distinguish between speech and music. In order to make such a classifier use the data in the directory `SpeechMusic` from the problem set archive. When you unzip it you will find two directories, one full of speech soundfiles and one full of music soundfiles.

Perform a spectrogram analysis on each file, take its absolute value and then its log. This is a very common representation for audio. Using this representation, each soundfile would provide you with lots of training spectral vectors (i.e. each column of this representation) for both speech and music.

Design a classifier that can distinguish between the two classes. The only design requirement is that given a second of audio data the classifier has to return a decision on whether the input is speech or music. Feel free to use any techniques you want. Also feel free to use an alternative representation as opposed to the one I suggested above. To evaluate your results put aside 10% of the training files to use as test data. Rerun the training a few times with a different set of test files each time. What are your recognition rates for each second of test data?

Now record your voice and find a piece of music that you like. Make sure you use the same sampling rate and put it through the classifier. Does it work?

Just as before, you are free to use existing code for your experiments, but the more code you write yourself the more extra credit you will get. Make sure to report what code you have used.

Problem 4. A pool detector (graduate students)

You have to make a swimming pool detector. Use the image `ekalismall.png` to train a classifier, and evaluate its performance on `ekalismall2.png`. The TAs or I will not answer any questions on this problem, you are on your own. Have fun!

PART III – PROJECT PROPOSAL

Propose a project you would like to do for this class. Make sure that this project is related to the material we covered. It is ok if your project involves research you are already working on, but if so it will have to meet higher standards. If you are an undergrad, pick something doable that will make your resume look good for job/grad school interviews. Either way, do not try to solve the world's greatest problems in a month.

Find a partner for your project, we do not have enough time to present/grade all projects otherwise. Put your proposal on all homeworks submitted by your team, make sure you mention your partner's name in each. Don't get lazy and ask to go solo because you don't know how to incorporate a partner to your planned project. A big part of research is compromising while collaborating, another big part is managing partners.

I suggest that your proposal has three parts:

1) A problem that you will definitely be able to solve by the end of the semester, so at worst case you will have something to show.
2) A further elaboration on that problem that is more technically challenging and more in line with a good final project.
3) Yet another elaboration that if resolved will be so good that it will be worthy of publication.

For example, a few years ago we had a student that proposed: 1) A neural network that will denoise voice (something known to be doable), 2) a further extension using a specific RNN architecture which should work better (it did), 3) Using that network to separate voice from real music recordings (ended up being a paper with a couple hundred citations so far). Don't just send in a proposal to use a humongous neural net to solve all of world's problems, it will very likely not work and does how exhibit a good understanding of things should be done.

You will eventually be expected to write a technical paper describing any prior work, what you have done (methodology, results, etc), and, if you are so inclined, what the future steps might be. We will have a poster session at the end of the semester, and you might also have to give a 15/20-min class presentation during one of the preceding classes.

Past students got conference papers, and started off in their thesis research using projects from this class. I suggest you think along the same lines. Don't waste all your effort for just a class project; make something more of it.

Good luck!