EECE 5136/6036: Intelligent Systems

Homework 4: Given 10/14/20; Due 11/12/20

This homework is a continuation of Homework 3. You should use the same code and training/test datasets for this homework. You should have laid the groundwork for this homework in Homework 3, so this should not take nearly as much time.

1. (200 points) In this problem, you will repeat Problem 2 from Homework 3 with a small change. In training the autoencoder, you should add a small amount of random noise to your input images, but still require the network to output the correct image. Thus, while the actual input to the network will be a noisy input $x^q + noise$, the loss will still be calculated based on the correct input x^q. This is the denoising autoencoder discussed in class.

You will need to choose the type and amount of noise. Since the pixel intensities in the dataset are between 0 and 1, an especially easy type of noise is to randomly set a fraction f_0 of pixels to 0 and a fraction f_1 to 1 (e.g., f_0 could be 0.4 and f_1 0.05, reflecting the fact that most pixels in the image are already close to 0.) There are many other ways you can add noise, but make sure the noisy input pattern still has pixel intensities between 0 and 1. You should experiment with different types of noise and noise levels (e.g., the f_0 and f_1 values) to see what gives reasonably good results but still adds significant noise.

Once you have decided on a noise model, use it to get and plot the same data for this case as you did for the regular autoencoder in Problem 2 of Homework 3, and compare the results for the two cases. In particular, comment on whether the two autoencoders learned similar or different features in the hidden layer, and if different, in what way?

Note that the denoising autoencoder may not achieve a performance similar to the regular autoencoder because it is solving a harder problem. You can make up for this to some extent by training longer and using a proportionately smaller learning rate in the current case. Just note in your report what you did.

The format and length of your report for this problem should be the same as for Problem 2 of Homework 3. *However, make sure you also describe the noise model you chose to use, and why.*

2. (200 points) In this problem, you will repeat Problem 1 from Homework 3 using the simulator you developed and the same training and testing sets as before, but with one big difference. This time, instead of setting the weights from the inputs to the hidden neurons randomly, you will set them to the final weights from the input to the hidden layer obtained after training the autoencoders in Problem 2 from Homework 3 or in Problem 1 in this homework, and then you will only train weights from the hidden layer to the output units using back-propagation (actually LMS, because now you are only training one layer). Basically, you are using the feature detectors found by the auto-encoder as pre-trained hidden neurons for the classification problem, relying on the assumption that the auto-encoder must have found high-quality features in order to achieve good reconstruction, and that these features are informative enough to be the basis of classification without further training.

Specifically, you will do two cases:

Case I: Train a network where the weights from input to hidden neurons are set to the final values of the same weights from the best final network obtained in Problem 2 of Homework 3, while the weights from hidden to output neurons are initialized randomly. During training, each data point is presented to the network and, after the error is calculated, only the hidden-to-output weights are adjusted. The input-to-hidden weights remain fixed.

Case II: Repeat the process in Case I using the final hidden neurons and weights from the denoising autoencoder in Problem 1 above.

Thus you will get two sets of results – one using the hidden layer of the regular autoencoder from Homework 3 and one using the hidden layer of the denoising autoencoder.

Follow all the same procedures for collecting data and results as in Problem 1 of Homework 3, and write a report with the following sections:

- **System Description:** A description of all the choices you made – learning rate, momentum, output thresholds, rule for choosing initial weights, criterion for deciding when to stop training, etc. Describe this for both cases.
- **Results:** Report performance of the final Case I and Case II networks on the training set and the test set using confusion matrices just as you did in Homework 3. Also plot the time series of the error (1 - balanced accuracy) during training using the data saved at every tenth epoch for both networks.
- **Analysis of Results:** Describe, discuss and interpret the results you got, and why you think they are as they are. In particular, comment on what differences, if any, you see in the performance of network from Problem 1 in Homework 3 and the networks obtained in this problem.

The text part of the report, including the figures, should be no more than 4 pages, 12 point type, single spaced. Since this problem does not require any new program, you do not need to include a program with this.

Note on Figures:
Each figure in each answer should be given a distinct name (Figure 1.2, Figure 2.1), etc. and caption, and should be referred to by its name in the text – not as "the figure below" or "the next figure". If you have multiple panels in one figure, they should be labeled (a), (b), (c), etc., and referred to in the text as Figure 2.3(a), Figure 3.1(c), etc., and not as "the top left panel of Figure 2.3". Refer to the sample report from Homework 1 for style in general.

Appendix: Programs: No code needs to be submitted with this homework because the programs used in this homework are the same as those used in Homework 3.

As in previous homeworks, the report should be a stand-alone document with text, tables, figures, etc. *None of the information required in the report should be given as a comment or note in the program. It must all be in the report.*

Report Instructions:

Please follow the instructions given for previous homeworks.

Submission Instructions:

You should submit your report on-line through Canvas following the process given for Homework 3.

Grading:

Points will be awarded for correctness of the results, proper plots, and the clarity of description and conclusions.

You may consult your colleagues for ideas, but *please write your own programs and your own text.* Both the text of the reports and the code will be checked randomly for similarity with that of other students. *Any text or code found to be copied will lead to an automatic zero on the entire homework for all students involved.* Repeat offenses in the future will incur more severe consequences.

If you have questions, please send me mail at. Ali.Minai@uc.edu.