EECE 5136/6036: Intelligent Systems

Homework 4: Given 11/14/22; Due 11/29/22

1. (300 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 in HW 3.

You must use the same learning rate and momentum values, the same H and L thresholds, and the same number of hidden neurons in this problem as you did in the final network of HW 3, Problem 1. You should also train for the same number of epochs as you did there.

You will then do 2 cases:

Case I: Set the input-to-hidden layer weights from the autoencoder and hidden-to-output weights randomly. Then train *only* the weights from the hidden layer to the output units using back-propagation (actually LMS, because now you are only training one layer). The input-to-hidden layer weights remain fixed to the values you set them to. Basically, you are using the feature detectors found by the autoencoder as pre-trained hidden neurons for the classification problem, relying on the assumption that the autoencoder 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.

Case II: As in Case I, set the input-to-hidden layer weights from the autoencoder and hidden-to-output weights randomly, but this time train both layers of weights using backpropagation. This is just a repeat of Problem 1 from HW 3, except that the input-to-hidden weights are initialized from the autoencoder. Note that Case II should be done separately from Case I, using random initial weights from hidden to output layers.

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:

- **Results:** Report performance of the final Case I and Case II networks on the training set and the test set using confusion matrices, and mean training and test error bar plots (overall and for each digit). just as you did in Homework 3. Also plot the time series of the error fraction 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. Comment on what differences, if any, you see in the performance of all three classifier networks (the network from Homework 3 and the networks obtained in this problem). In particular, answer the following questions:

  Q1: Did initializing the hidden weights from the autoencoder make training go faster in this this homework compared to that in HW 3 (for both Case I and Case II)?

  Q2: Did training both layers (Case II) substantially improve performance over training only the output layer (Case I)?

The report, including the figures, should be no more than 4 pages, 12 point type, single spaced.

2. (200 points) In this problem you will train an *auto-encoder network* just as you did in Problem 2 or HW 3. However, this time you will use only data for digits 0, 1, 2, 3 and 4 to train the autoencoder. As before, you will use 400 points of each digit for training and 100 for testing to determine whether the network is sufficiently trained. Once the network is trained, you will test it on digits 5, 6, 7, 8 and 9 *without further training*. You may use the same learning rate, momentum, or the number of hidden neurons as you used in HW 3, but this is not required.

Write a report providing the following information. Each item required below should be placed in a separate section with the heading given at the beginning of the item.:

- **System Description:** A description of all the parameter choices you made – learning rate, momentum, rule for choosing initial weights, criterion for deciding when to stop training, etc. Again, you may need to try several parameter values.
- **Results:** As in Problem 2 of HW 3. report the performance of the final network on the training set and the 0-to-4 test set using the loss function. In this case, this will just be two values, which you should plot as two bars side by side. Then plot the same error in the same way, but separated by each digit – so there will be two bars for 0, two for 1, etc. In a separate figure, plot the loss values for the 5-to-9 digits as a bar graph.
- **Sample Outputs:** Choose 5 samples randomly for each digit from 0 to 9. The 0 to 4 samples should come from the 0-to-4 test set, and the 5 to 9 samples can be from the whole 5-to-9 test set. For each of these show (one above the other) the original (input) image and the output image produced by the network after training. Thus, you will have 10 pairs or rows with of 5 images each. The upper row of each pair will be the actual images, and the lower row will be the output images for the same inputs.
- **Analysis of Results:** Describe, discuss and interpret the results you got, and why you think they are as they are. In particular, comment on which of the untrained digits turned out to be easiest to reconstruct and which ones more difficult, and why you think that happened.

The text part of the report, including the figures, should be no more than 4 pages, 12 point type, single spaced.

Report Instructions:

Please follow the instructions given for previous homeworks.

Submission Instructions:

You should submit your report on-line through Canvas. Your submission will have three documents: 1) A report as described above; 2) A file (or .zip file) with all your source code; and 3) A brief README file with instructions on how to compile (if needed) and run the code. If Canvas does not let you submit a file with the type postfix (.py, .m, etc.) of a source code file, try changing the postfix manually to .docx or .txt and submit it. State in the README file what the postfix should be changed to in order to run the code. **Note that a .zip file can be used** *only)* **for the code.** *Your report and README files must be in Word or PDF.*

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 cannot access the data, please send me mail at. Ali.Minai@uc.edu.