DAT565/DIT407
Introduction to Data Science and AI

Assignment 6
Deadline: 2024-12-14 12:00

In this assignment, we analyze the MNIST handwritten digits dataset [1] using neural networks. The dataset consists of greyscale images of hand written digits $0, 1, \ldots, 9$ that have been normalized to 28×28 bitmap images. Each image is accompanied by the correct label. We will construct a classifier that classifies the images to their correct labels.

Problem 1: The dataset

Set up PyTorch in your Anaconda environment. The following invocation should install the CPU only version:

```
conda install -c pytorch pytorch torchvision cpuonly
```

Load the dataset (both training and test set) using the `torchvision.datasets` module. Note that the you probably want to use the `transform` option to convert the images into `Tensors`. By default, the images come as PIL[1] images.

Use matplotlib to plot some images in greyscale, and include at least one from each set in your report. Verify that the images have the correct dimensions (28×28) and scale for values (values should be normalized to be in range $[0, 1]$).

Problem 2: Single hidden layer

Construct a fully-connected feedforward network with one hidden layer. Use the ReLU as the activation function. Train the network for at least 10 epochs using stochastic gradient descent (`torch.optim.SGD`) for optimization and cross entropy loss (`torch.nn.CrossEntropyLoss`) for loss function. Report the *validation accuracy* of your network (with respect to the test set) after each epoch. Report all relevant parameters you chose.

Problem 3: Two hidden layers

Construct a fully-connected feedforward network with two hidden layers that have 500 and 300 units, respectively. As before, use ReLU, SGD, and cross entropy loss. In addition, enable L_2 regularization using a suitable (probably rather small) value for the `weight_decay` parameter of the optimizer. Train the network for at least 40 epochs and report the validation accuracy after each epoch. You should be able to achieve an accuracy of at least 98%.

[1] Python Imaging Library.

Problem 4: Convolutional neural network

Construct a feedforward network with at least two convolutional layers. As before, use ReLU, SGD, and cross entropy loss, and choose a suitable value for weight loss. Train the network for at least 40 epochs and report the validation accuracy after each epoch. You should be able to reach an accuracy of at least 99%. If you cannot reach that value, then report the value you reached anyway. Describe the structure of your network, and all relevant parameter choices you made.

Hints

- The MNIST dataset is also available on Canvas, but it is in an unwieldy format, it is much easier to download the dataset using PyTorch functionality.
- Have a look at PyTorch documentation and the tutorial at `https://pytorch.org/tutorials/beginner/basics/intro.html`.
- Learn how to use datasets and dataloaders.
- Matplotlib can plot bitmap images using the function `imshow`.
- Remember also to consider how the other parameters not mentioned in the instructions affect your model and its training, such as the learning rate and the number of hidden units.
- Be sure you understand what is the dimensionality of the tensors at each step of the evaluation process (function `forward`).
- Study the examples carefully.
- If you want to access the website of the MNIST dataset, do note that there is a bug in the web server and it is inaccessible with Chrome: `https://twitter.com/ylecun/status/1628746102827630593`.

Returning your report

Write a report, typeset in LaTeX, that answers *all* questions above. Include all your Python code in your report as an appendix, preferably using the `listings` package. Your report should be legible even without having a look at your code.

If you refer to outside sources, remember to add an appropriate literature reference (including websites) in references by `\cite`ing the references. It is recommended that you use the package `biblatex` to manage citations.

Place your figures in numbered `figure` environments, with descriptive captions and `\ref` to the figures in your discussion. Likewise, place your tables in numbered `table` environments with desciprive captions and `\ref` to the tables in your discussion.

After grading, you will be given another attempt to revise your report according to TA comments if it is not considered acceptable.

The deadline is *hard*. Late submissions will not be read at all and are considered failed. This means you will not get any feedback for the first round and the submission is considered a revision; there will be no third attempt, so if a late submission is failed, you will need to participate in a later iteration of the course for a re-attempt.

References

[1] Yann LeCun, Corinna Cortes, and Christopher J.C. Burges. *The MNIST database of handwritten digits*. Retrieved 2024-01-02. 1998. URL: `http://yann.lecun.com/exdb/mnist/`.