

Artificial Neural Networks

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Problem Set 11: Deep Neural Networks 2

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1. **Learning rate in DNN.** Build a deep convolutional neural network similar to the one in problem set 10, problem 3, but insert a new dense layer with ReLU activation function and 64 units between the last max pooling layer and the output layer. As optimizer use `keras.optimizers.SGD`.
 - (a) Train models with varying learning rates $\eta \in \{1, 0.1, 0.01, 0.001, 0.0001\}$ on the first 20,000 samples of the fashion MNIST training data set. Train each model for a total of 10 epochs. After each epoch evaluate the accuracy and loss on the training set. **Note:** Make sure to rebuild your model and compile it with the new learning rate. Just calling `model.compile` is not enough, since it does not reinitialize the weights of your model.
 - (b) Plot accuracy and loss for each model as a function of trained epochs. How do the different learning rates affect the speed of learning? Can the choice of learning rate prevent the model from learning?
2. **Overfitting in DNN.** Reuse the model architecture of the previous problem and increase the number of units of the last hidden layer to 128. You may use `keras.optimizers.Adam` as optimizer.
 - (a) Train models on varying training set sizes $N \in \{30000, 15000, 2500, 500\}$ of the fashion MNIST data set. Train each model for 10 epochs. Evaluate accuracy and loss on both the training set and the test set.
 - (b) Plot accuracy and loss for each model as a function of training set size. How does the size of the training set affect accuracy and loss on the test set?
3. **Data Augmentation.** The images in the fashion MNIST dataset are standardized (crop, scale and orientation) to make it easier to train neural networks. Of course, real images are not standardized. To simulate a more realistic dataset, we use the *ImageDataGenerator* (from `keras.preprocessing.image`), a preprocessing tool that generates augmented data by applying various transformations (rotation, zoom, deformations, etc.) to your original data set. Normally, it is used for data augmentation to increase the size of and variability in your training data set.
 - (a) Initialize an *ImageDataGenerator* object and use its *flow* function to create an iterator from the first 10,000 samples of the fashion MNIST training set. During initialization of the *ImageDataGenerator* object use the following parameters:
 - i. `rotation_range: 20`
 - ii. `width_shift_range: 0.1`
 - iii. `height_shift_range: 0.1`
 - iv. `shear_range: 0.5`
 - v. `zoom_range: (0.9, 1.1)`
 - vi. `fill_mode: 'constant'`Iterate over the iterator object to acquire pretend data until you have generated roughly 20,000 samples. Split the data 50/50 into training $Train_{pret}$ and test $Test_{pret}$ sets. Save the pretend data set for later use. **Note:** Iterator objects can be iterated over indefinitely and require manual stopping.

- (b) Reuse the model architecture of problem 1 and use *keras.optimizers.Adam* as optimizer with a learning rate of $\eta = 0.01$. Train the network on the training data in the original fashion MNIST dataset $Train_{orig}$ for one epochs and save it. (**Note:** You can save your model by calling its *save* function.) By saving the model you save the architecture, the weights as well as the optimizer and its hyperparameters. Let's call this model M_{orig} .
- (c) Evaluate M_{orig} on the original test set $Test_{orig}$ and the pretend test set $Test_{pret}$. We will refer to these accuracies as $M_{orig}(Test_{orig})$ and $M_{orig}(Test_{pret})$. Why does the accuracy differ between the two sets?
- (d) Train the same model architecture as above on $Train_{pret}$ pretending that the pretend data was real data. Evaluate the accuracy of this model M_{pret} on $Test_{pret}$. Compare $M_{pret}(Test_{pret})$ to $M_{orig}(Test_{pret})$. What did you expect?
- (e) Train the model on $Train_{pret}$ with data augmentation for one epoch. To do so, call *model.fit_generator* with the *ImageDataGenerator* object you created and *steps_per_epoch* set to 4000 (for more information check the Keras documentary). We'll call this model M_{aug} . Compare $M_{aug}(Test_{pret})$ to $M_{pret}(Test_{pret})$. What did you expect?

4. **Transfer learning.** To illustrate transfer learning, we reused the previously trained network M_{orig} .

- (a) Load the trained network from problem 3. (**Note:** To load your previously saved model you have to import the *load_model* function from *keras.models*.) Also load the pretend data set you generated in problem 3.
- (b) Train the loaded model M_{orig} for one additional epoch on the first 500 samples of the pretend training set $Train_{pret}$. Also train a network of the same type *de novo* on the same 500 samples. Call this model M_{novo} . Evaluate the test accuracy for both models. Repeat this for the full pretend training set $Train_{pret}$. How do accuracies differ in these two cases?