Machine Learning
Second Assignment

Deadline: 21 Jan 2020

The exercise should be implemented in the Python programming language using Keras.

- Code snippets to aid you with your exercise can be found in e-class.
- Your final report should contain enough details to make your results reproducible.
- For exercise 3 you are free to use any publicly available data set as long as you specify what you have used. You may also augment any of these data sets as you see fit.

Installation

- The python installation procedure depends on your operating system. You can find information to help you with your installation online. Make sure you also install the pip tool. If you are using Ubuntu 18.04, python is already installed and pip can be installed with the comand "sudo apt-get install python-pip".
- Once you have installed python and pip, type in your terminal "pip install keras tensorflow matplotlib numpy". You can install any additional library using "pip install ⟨ library_name ⟩".
- Additional resources to help you get familiar with Python and Keras will be uploaded in e-class.

Exercise 1. *40%*

(A) Rewrite the general form of the backpropagation equations given in class for MLPs for the following specific activation functions i) ReLU, ii) hyperbolic tangent and iii) sigmoid. For each activation function write down the range of the gradients.

(B) Download the MNIST data set and use it to train a fully-connected neural network to recognise handwritten digits. The MNIST data set can be loaded from *keras.datasets*. Make sure that your data is normalized. Each hidden layer should have 32 units and the output layer should have a softmax activation function. Compile your model to use the standard SGD optimizer with a learning rate of 0.01 and the categorical crossentropy loss function. Use (i) 5, (ii) 20 and (iii) 40 layers. For each choice (i), (ii) and (iii), use the (a) ReLU, (b) hyperbolic tangent and (c) sigmoid activation function on all hidden layers. Report the test scores for each model. What are your observations?

(C) For each of the models in (B), trained for 3 epochs on the MNIST data set, compute for each layer the maximum value of the gradient on a given mini-batch and create a plot of "layer depth vs. max gradient". Organize your plots as a grid so that your results for the different activation functions for each depth choice appear on the same subplot. Can you explain your observations? What insight do you gain for the observations in (B)?

(D) Train a model using the topology given in (B) and the activation function

$$LeCun(x) = 1.7159\ tanh(\frac{2}{3}x) + 0.01x.$$

Compare the learning curves of the models using LeCun and hyperbolic tangent activation functions. Write down the backpropagation equations and the gradient range for the LeCun activation function. Plot the gradients for the choices of depth given above for an untrained model using LeCun and hyperbolic tangent activations.

Exercise 2. *20%*

(A) Download the Street View House Numbers (SVHN) data set and train a convolutional neural network for classification. The data set can be found here *http://ufldl.stanford.edu/housenumbers/*. Your topology should be as follows: Use 3 convolutional layers and 3 max pooling layers interchangeably, then flatten your output and perform multi-label logistic regression on it. Use a 3×3 kernel for both your convolutional and max pooling layers. Use 9, 36 and 49 filters for your convolutional layers. Use an early stopping callback to monitor the validation loss of your model on a validation set of 7326 images (randomly chosen from the train set). Plot your model's confusion matrix.

(B) For a randomly chosen image from each class, plot your model's output for each convolutional filter and group your plots by layer on grids. What do you observe?

Exercise 3. 40%

Train a classifier to recognise handwritten digits. Your model must be saved in .h5 format and will be tested on digits written by us. Your marks for this exercise will be $40 * \frac{your\_test\_accuracy}{your\_class\_best\_test\_accuracy}$.