Universität des Saarlandes
FR 4.7 Sprach- und Signalverarbeitung

Prof. Dietrich Klakow
Pattern and Speech Recognition

Exercise Sheet 10

Sequence Modelling: Recurrent Neural Networks

Deadline: 31.01.2017, 23:59

Power Method

Exercise 10.1

In this exercise, you will implement Power Method to find the eigenvector of a matrix corresponding to the largest eigenvalue by magnitude. It helps to understand the concept of exploding/vanishing gradients while training RNNs. (Chapter 9, slide 31)

a) Consider the matrix,

$$M = \begin{bmatrix} -2 & -2 & 3 \\ -10 & -1 & 6 \\ 10 & -2 & -9 \end{bmatrix}$$

Find its eigenvalues and the eigenvector v corresponding to the largest eigenvalue by magnitude analytically. ($\|v\|_2$=1) *(2 pts)*

b) Start with a random vector u to initiate the computations of Power Method, repeat until $|\langle u, v\rangle| \approx 1$. Resize the vector u after each iteration s.t. $\|u\|_2$=1. *(2 pts)*

c) Store the value of $|\langle u, v\rangle|$ for each iteration and plot its value against number of iterations. *(1 pt)*

Sequence Prediction using RNN

Exercise 10.2

In this task, you will train a RNN with a sequence of nucleotide bases of a given DNA snippet. The sequence contains 4 elements/nucleotide bases: adenine(A), cytonsine(C), guanine(G), thymine(T).

a) Download the file *data.txt* from the course webpage. Write a function to read the file and store the whole sequence as a string. *(2 pts)*

b) Write a function to extract a random chunk of length k from the sequence. These random chunks are used to train the RNN. *(2 pts)*

c) Write a function to encode each element of a given chunk as a *one-hot vector*. Add a vector of zeros in the beginning, which acts as *Start of Sequence(SoS)* symbol. For a given chunk of length k, the function should return a numpy array of shape $(k+1, 4)$ *(2 pts)*

d) Implement a simple RNN with network architecture defined in slide 11 of chapter 9 using Tensorflow. Let $h \in R^4$. Use softmax cross-entropy to compute the loss and $ADAM$ optimizer for backpropagation with learning rate $= 10^{-4}$.*(5 pts)*

e) To train the network, extract a random chunk x of length $k = 5$ from the sequence, encode it and feed into the network. If $x^{(i)}$ is the i^{th} element of the chunk, use the element at $x^{(i+1)}$ as $y^{(i)}$. (since the task is sequence prediction) *(3 pts)*

f) Repeat it for 50000 iterations, compute the average loss for every 100 iterations and plot the result. *(1 pts)*

Bonus

Exercise 10.3

In this task, you will measure the perdiction performance of the RNN model using *perplexity*. For details about perplexity, refer: https://en.wikipedia.org/wiki/Perplexity

a) Compute *perplexity* $= 2^{-\frac{1}{N}\sum_{i=1}^{N} log_2 P(x^{(i)}|x^{(i-1)}, h^{(i-1)})}$ for the whole sequence of training data, where $P(x^{(i)}|x^{(i-1)}, h^{(i-1)})$ is the output of the softmax layer for the element $x^{(i)}$. *(4 pts)*

b) To interpret the value of perplexity, consider the following cases: If the model predcits each element in the sequence correctly with $p(x^{(i)}|x^{(i-1)}, h^{(i-1)}) = 1$, then value of perplexity is 1. Other extreme case is when the predictions by the model are random, all outcomes are equiprobable and value of perplexity will be 4.

   Based on the perplexity value you have obtained, what can you say about the performance of the model? *(1 pt)*

Submission instructions

The following instructions are mandatory. If you are not following them, tutors can decide to not correct your exercise.

Submission architecture

You have to generate a **single ZIP file** respecting the following architecture:

```
tutorial10_<matriculation_nb1>_<matriculation_nb2>_<matriculation_nb3>
|
+--- source
|      |
|      +------- file 1
|      +------- file 2
|      +------- ...
+--- report.pdf
+--- README.txt
```

where

- **source** contains the source code of your project,
- **report.pdf** is the report where you present your solution with **the explanations** and the plots.
- **README** which contains group member informations (name, matriculation numbers and emails) and a **clear** explanation about how to compile and run your source code

The ZIP filename has to be :

`tutorial10_<matriculation_nb1>_<matriculation_nb2>_<matriculation_nb3>.zip`

Some hints

We advice you to follow the following guidelines in order to avoid problems :

- Avoid building complex systems. The exercises are simple enough.
- Do not include any executables in your submission, as this will cause the e-mail server to reject it.

Grading

Send your assignment to the tutor who is responsible of your group:

- Merlin Köhler s9mnkoeh@stud.uni-saarland.de
- Goutam Y G goutamyg@lsv.uni-saarland.de
- Ahmad Taie s8ahtaie@stud.uni-saarland.de

The email subject should start with `[PSR TUTORIAL 10]`