CS7.501 | Advanced NLP| Assignment - 1

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General Instructions

1. You should implement the assignment in Python, using only Pytorch library as the Neural Network Framework.
2. Ensure that the submitted assignment is your original work. Please do not copy any part from any source, including your friends, seniors, and/or the internet. If any such attempt is caught, serious actions, including an F grade in the course, are possible.
3. A single .zip file needs to be uploaded to the Courses Portal.
4. Your grade will depend on the correctness of answers and output. Due consideration will also be given to the clarity and details of your answers and the legibility and structure of your code.
5. Please start early to meet the deadline. Late submissions won't be evaluated.

1 Neural Network Language Model

1.1 About

Language modeling (LM) is the use of various statistical and probabilistic techniques to determine the probability of a given sequence of words occurring in a sentence. Thus, it may be defined as a probability distribution over the vocabulary words. In traditional N-gram Language Models, the probabilities of words occuring after a given context are defined as:

$$P(w_1, \ldots, w_m) = \prod_{i=1}^{m} P(w_i \mid w_1, \ldots, w_{i-1}) \approx \prod_{i=2}^{m} P(w_i \mid w_{i-(n-1)}, \ldots, w_{i-1}) P(w_1, \ldots, w_m)$$

$$= \prod_{i=1}^{m} P(w_i \mid w_1, \ldots, w_{i-1}) \approx \prod_{i=2}^{m} P(w_i \mid w_{i-(n-1)}, \ldots, w_{i-1})$$

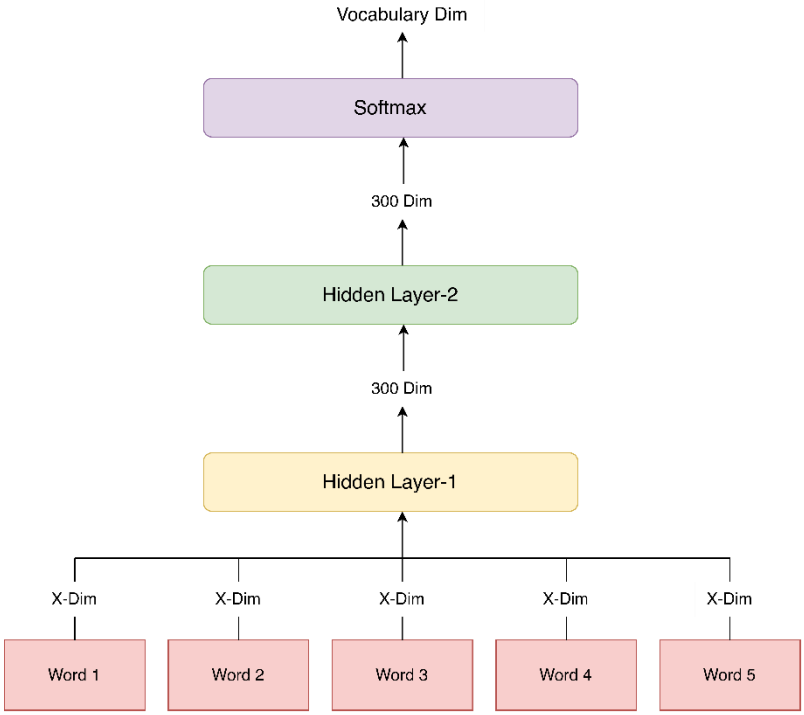
This part involves creating a Neural Language Model using standard Deep Learning Frameworks with a 5-gram context.

1.2 Model Architecture

The architecture of the Language Model is described below:

1. The input to the Neural Network would be the pre-trained embbeddings of the previous 5-words concatenated together(5-gram embedding).
2. These embedding would pass into a Hidden Layer which would output a 300-dimension vector.
3. The output of the first Hidden Layer would go into another Hidden Layer, which would output a vector of size vocabulary.
4. This vector would be passed to a Softmax Layer, which would output the probabilities of entire vocabulary occuring after the given 5-words.
5. The vocabulary should consist of all the words that occur any number of times in the training data. Unknown words can be handled with an <UNK> token.

6. You are allowed to use **only Pytorch** as the Deep Learning Framework for this assignment.
7. You can use any pre-trained embeddings as input to the Neural Network - word2vec, GloVe, fasttext, etc.



1.3 Dataset

1. You need to create Neural Language Model described above trained on Auguste_Maquet corpus.
2. You are expected to clean the data to remove any special characters and use it for training the Neural LM. You can use libraries for tokenization.
3. You can download the corpora from this link. Sample 10,000 sentences as validation set and 20,000 sentences as test set.

1.4 Marks Distribution

1. Implement the Language Model and report the Perplexity Scores. [40 marks]
2. **Bonus** Plot graphs showing the variation of average train/test perplexities with varying hyperparameters like Dropout rate, changing the dimensions of the layers, changing the Optimizer, etc. Report the most optimal Hyperparameters found. [10 marks]

2 RNN-based Language Model

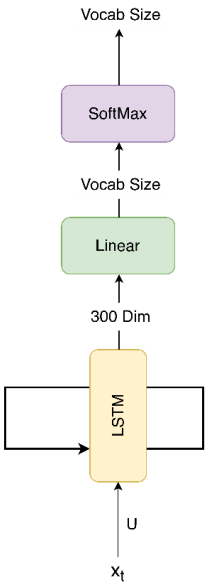
2.1 About

To solve some problems arising from using a much smaller(5-gram here) context for next word, Recurrent Neural Networks(RNN) were used to improve the architecture. In this part, you will create such a Neural Language Model using LSTM, while implementing LSTM functions using the standard LSTM class.

2.2 Model Architecture

The architecture of the Language Model is described below:

1. The Neural Network would consist of repeating layers in an LSTM-structure.
2. The input to each layer would consist of the hidden-layer and cell state output of the previous state, along with the embedding of the current word.
3. The 300-dimension output would be put into a Linear layer, which will transform it to vector of dimension of size vocabulary. Then, that to SoftMax-layer, which would provide the probability distribution over the entire vocabulary.



2.3 Dataset

You are supposed to use the Dataset from the previous task for this task as well, with the same training and validation data sizes.

2.4 Marks Distribution

1. Implement the Language Model and report the Perplexity Scores. [60 marks]

3 Transformer Decoder based Language Model:

3.1 About

This programming exercise will give you the chance to use the Pytorch to implement a language model in accordance with the Transformer Decoder architecture. Modern language models, such as OpenAI's GPT series, rely heavily on the Transformer Decoder. In this assignment, you will implement the core components of the Transformer Decoder and train it to generate coherent and contextually relevant text. The task at hand involves constructing a language model with the capability to predict the subsequent word in a given sequence of words. The model will be trained on a text corpus , which then will learn to produce text that mirrors the structure and pattern of the training data.

Resources:

1. "Attention Is All You Need" paper: https://arxiv.org/abs/1706.03762
2. "Illustrated Transformer" blog post: http://jalammar.github.io/illustrated-transformer/

3.2 Dataset

You are supposed to use the Dataset from the previous task for this task as well, with the same training and validation data sizes.

3.3 Marks Distribution

1. Implement the Language Model using Transformer Decoder based architecture and report the Perplexity Scores. [50 marks]

4 Analysis

1. Analyse which of the models gives better perplexities on the train and the test/validation sets.
2. Compare the behaviour of the trained LMs and elaborate your findings using graphs and visualizations.

5 Submission format

Zip the following into one file and submit it on the Moodle course portal:

1. Source code (Should include .py files only.)
2. Language Model and the generated perplexity files.
3. For each LM submit the text file with perplexity scores in the following format
   - Format : Sentence TAB perplexity-score, at the end : average score
   - Naming must be: roll number-LM1-train-perplexity.txt, roll number-LM1-test-perplexity.txt, etc
4. Readme file (should contain instructions on how to execute the code, restore the pre-trained model, and any other information necessary for clarity)

Name the zipped file as <roll number>_<assignment1>.zip, e.g.: 2022xxxxxx_assignment1.zip.

Note: If the pre-trained models cross the file size limits, upload them to a OneDrive/GDrive and share the read-only accessible links in the readme file.

6 FAQs

1. Do I need to use lemmatization before feeding the samples to the model? No, for the sake of this assignment, you may not perform lemmatization.
2. I do not have enough compute. Can I reduce the working corpus size?
   Yes, you may reduce the vocabulary size. But make sure you train the model on enough no. of sentences, which should be a minimum of 30,000 sentences.
3. Can I submit my code in Jupyter Notebooks?

No, the final submission should be a Python script. You may work using a Jupyter Notebook, but make sure to convert it to .py file before submitting.

4. You can use libraries like Scikit-learn and Gensim to read vector files and use the pre-trained embeddings for the LM task.

7 Resources

7.1 Papers

1. Recurrent neural network based language model
2. A Neural Probabilistic Language Model

7.2 Explanatory supplements

1. Stanford lecture notes - LM & RNN
2. A simple, intuitive explanation of RNNs, LSTMs and GRUs
3. A Survey on Neural Network Language Models
4. GloVe: Global Vectors for Word Representation