**University of Central Missouri**

**Department of Computer Science & Cybersecurity**

**CS5720 Neural network and Deep learning**

**Spring 2025**

**Home Assignment 4. (Cover Ch 9, 10)**

**Student name:**

**Submission Requirements:**

* Total Points: 100
* Once finished your assignment push your source code to your repo (GitHub) and explain the work through the ReadMe file properly. Make sure you add your student info in the ReadMe file.
* Submit your GitHub link and video on the BB.
* Comment your code appropriately ***IMPORTANT.***
* Make a simple video about 2 to 3 minutes which includes demonstration of your home assignment and explanation of code snippets.
* Any submission after provided deadline is considered as a late submission.

**Q1: NLP Preprocessing Pipeline**

Write a Python function that performs basic NLP preprocessing on a sentence. The function should do the following steps:

1. **Tokenize** the sentence into individual words.
2. **Remove common English stopwords** (e.g., "the", "in", "are").
3. **Apply stemming** to reduce each word to its root form.

**Use the sentence:**

**"NLP techniques are used in virtual assistants like Alexa and Siri."**

The function should print:

* A list of all tokens
* The list after stop words are removed
* The final list after stemming

**Expected Output:**

Your program should print three outputs in order:

1. **Original Tokens** – All words and punctuation split from the sentence
2. **Tokens Without Stopwords** – Only meaningful words remain
3. **Stemmed Words** – Each word is reduced to its base/root form

**Short Answer Questions:**

1. What is the difference between stemming and lemmatization? Provide examples with the word “running.”
2. Why might removing stop words be useful in some NLP tasks, and when might it actually be harmful?

**Q2: Named Entity Recognition with SpaCy**

**Task:** Use the spaCy library to extract **named entities** from a sentence. For each entity, print:

* The **entity text** (e.g., "Barack Obama")
* The **entity label** (e.g., PERSON, DATE)
* The **start and end character positions** in the string

Use the input sentence:

**"Barack Obama served as the 44th President of the United States and won the Nobel Peace Prize in 2009."**

**Expected Output:**

Each line of the output should describe one entity detected

**Short Answer Questions:**

1. How does NER differ from POS tagging in NLP?
2. Describe two applications that use NER in the real world (e.g., financial news, search engines).

**Q3: Scaled Dot-Product Attention**

**Task:** Implement the **scaled dot-product attention** mechanism. Given matrices Q (Query), K (Key), and V (Value), your function should:

* Compute the dot product of Q and Kᵀ
* Scale the result by dividing it by √d (where d is the key dimension)
* Apply softmax to get attention weights
* Multiply the weights by V to get the output

**Use the following test inputs:**

***Q = np.array([[1, 0, 1, 0], [0, 1, 0, 1]])***

***K = np.array([[1, 0, 1, 0], [0, 1, 0, 1]])***

***V = np.array([[1, 2, 3, 4], [5, 6, 7, 8]])***

**Expected Output Description:**

Your output should display:

1. The **attention weights matrix** (after softmax)
2. The **final output matrix**

**Short Answer Questions:**

1. Why do we divide the attention score by √d in the scaled dot-product attention formula?
2. How does self-attention help the model understand relationships between words in a sentence?

**Q4: Sentiment Analysis using HuggingFace Transformers**

**Task:** Use the HuggingFace transformers library to create a **sentiment classifier**. Your program should:

* Load a pre-trained sentiment analysis pipeline
* Analyze the following input sentence:

**"Despite the high price, the performance of the new MacBook is outstanding."**

* Print:
  + **Label** (e.g., POSITIVE, NEGATIVE)
  + **Confidence score** (e.g., 0.9985)

### **Expected Output**:

Your output should clearly display:

***Sentiment: [Label]***

***Confidence Score: [Decimal between 0 and 1]***

**Short Answer Questions:**

1. What is the main architectural difference between BERT and GPT? Which uses an encoder and which uses a decoder?
2. Explain why using pre-trained models (like BERT or GPT) is beneficial for NLP applications instead of training from scratch.