

AI 534 Machine Learning HW4 (15 pts)

Instructions:

1. This homework is about using word2vec embeddings as features to train (averaged) perceptron (and optionally, other ML algorithms such as SVM) for sentiment classification, the same task we did in HW2. But instead of sparse features in HW2, we will use dense features from word embeddings here. The point of this homework is more about getting familiar with elementary deep learning.
2. You'll compete in this Kaggle <https://www.kaggle.com/t/99f316befcf34e62b01812a9194c387d> with team name being the last 5 digits of your OSU ID, like HW1 and HW2 (but unlike HW3). Part of your grade will depend on your scores on both the public and private leaderboards (the public/private test sets are identical to those in HW2). Reuse HW2 data, which includes training, dev, and semi-blind test files.
3. Download word embeddings from:
https://eecs.oregonstate.edu/~huanlian/teaching/ML/2025fall/unit4/hw4/embs_train.kv
4. You should submit to Canvas your `report.pdf`, `test.predicted.csv`, and all your code (`.py` or `.ipynb`).
5. As always, you are not allowed to use any extra data, including external contextualized embeddings which are trained on large corpora.

1 Word Embeddings (5 pts)

In natural language processing (NLP), a word embedding is a continuous representation of a word. The embedding is used in text analysis. Typically, the representation is a real-valued vector that encodes the meaning of the word in such a way that words that are closer in the vector space are expected to be similar in meaning. For example, word2vec¹ is one of the most widely used word embeddings model. In this section, we will use the word embeddings pretrained on part of google news dataset (about 100 billion words) as features, and each word is mapped to a 300-dimensional vector. We extracted the embeddings of those words appearing in `train.csv` and saved them in the provided file `embs_train.kv` (otherwise it's too big).

1.1 Load and Query (0 pts)

We use the Python package `gensim` to load and query `embs_train.kv`. This package is already installed on ENGR servers (`ssh access.engr.oregonstate.edu`), but if you'd like to use your own Python, you might need to install it by `pip3 install gensim`.

```
>>> from gensim.models import KeyedVectors
>>> wv = KeyedVectors.load('embs_train.kv')
>>> wv
<gensim.models.keyedvectors.KeyedVectors object at 0x7fa9a5b3e320>
```

The word embeddings are loaded into `wv`, which is a `gensim KeyedVectors` object. Now, we can query the embedding of each word in sentence `the man bit the dog`.

```
>>> wv['big']
array([ 0.11132812,  0.10595703, -0.07373047,  0.18847656,  0.07666016,
        -0.3828125 , -0.0625      , -0.07470703,  0.05957031,  0.22167969,
        ...,

```

¹<https://code.google.com/archive/p/word2vec/>

```

-0.17675781, -0.08984375, -0.09667969, -0.11669922, -0.09082031,
-0.02490234, -0.00509644, -0.07226562,  0.03735352, -0.15625   ],
dtype=float32)
>>> wv['dog']
array([ 5.12695312e-02, -2.23388672e-02, -1.72851562e-01,  1.61132812e-01,
-8.44726562e-02,  5.73730469e-02,  5.85937500e-02, -8.25195312e-02,
...,
-2.75390625e-01,  2.61718750e-01,  2.46093750e-01, -4.71191406e-02,
 6.25000000e-02,  4.16015625e-01, -3.55468750e-01,  2.22656250e-01],
dtype=float32)

```

1.2 Vector Similarity (2.5 pts)

We can query the most similar words for a given word based on “cosine similarity”.

```

>>> wv.most_similar('dog', topn=10)
[('dogs', 0.8680489659309387), ('puppy', 0.8106428384780884),
('cat', 0.7609457969665527), ('canines', 0.7221246361732483),
('pet', 0.7164785861968994), ('collie', 0.6714409589767456),
('puppies', 0.6637065410614014), ('pug', 0.6611860990524292),
('terrier', 0.6599656343460083), ('poodle', 0.6549598574638367)]
>>> wv.most_similar('man', topn=10)
[('woman', 0.7664012908935547), ('boy', 0.6824870705604553),
('teenager', 0.6586930751800537), ('girl', 0.5921714305877686),
('men', 0.5489763021469116), ('guy', 0.5420035123825073),
('person', 0.5342026352882385), ('suspect', 0.5247485041618347),
('victim', 0.5230302214622498), ('thief', 0.5138294100761414)]

```

Q: Can you find the top-10 similar words to *wonderful* and *awful*? Do your results make sense? (1 pt)

Q: Also come up with 3 other queries and show your results. Do they make sense? (1.5 pts)

1.3 Word Analogy (2.5 pts)

The word vectors capture many linguistic regularities, for example vector operations

$$\text{vector}(\text{'bigger'}) - \text{vector}(\text{'big'}) + \text{vector}(\text{'good'})$$

results in a vector that is very close to $\text{vector}(\text{'better'})$, and

$$\text{vector}(\text{'king'}) - \text{vector}(\text{'man'}) + \text{vector}(\text{'woman'})$$

is close to $\text{vector}(\text{'queen'})$, which can be demonstrated as following.

```

>>> wv.most_similar(positive=['bigger', 'good'], negative=['big'], topn=5)
[('better', 0.7805920839309692), ('stronger', 0.607010543346405), ('worse', 0.56091910600662),
('decent', 0.5300450921058655), ('excellent', 0.5028262734413147)]
>>> wv.most_similar(positive=['king', 'woman'], negative=['man'], topn=5)
[('queen', 0.7118193507194519), ('monarch', 0.6189674139022827), ('princess', 0.590243101119),
('kings', 0.5236844420433044), ('queens', 0.5181134343147278)]

```

Q: Find top 10 words closest to the following two queries. Do your results make sense? (1 pt)

$\text{sister} - \text{woman} + \text{man}$ and $\text{harder} - \text{hard} + \text{fast}$.

Q: Also come up with 3 other queries and show your results. Do they make sense? (1.5 pts)

2 Better Perceptron using Embeddings (6.5 pts)

2.1 Sentence Embedding and k -NN (3 pts)

We continue to treat each sentence as a collection of individual words, referred to as a “bag of words.” To represent the sentence, we calculate the average of the embeddings of its constituent words. For example, the sentence embedding of `the man hit the dog` is computed as below.

```
>>> (wv['the'] + wv['man'] + wv['hit'] + wv['the'] + wv['dog'])/5
array([ 1.51464850e-01,  9.12353545e-02, -4.32617180e-02,  8.23242217e-02,
       -2.34497078e-02, -2.36328132e-02,  3.10546868e-02, -8.69018584e-02,
        ...,
       -1.01428226e-01,  4.88281250e-02,  1.11816404e-02, -4.30419929e-02,
        3.66699211e-02,  4.65820320e-02, -7.85644501e-02,  1.79199222e-02],
      dtype=float32)
```

Note that `wv` might not have embeddings for some words in `dev.csv` and `test.csv`; just ignore them. No need to prune one-count words (although that would be better). Also note 1-NN could be wrong (as in HW1).

1. For the first sentence in the training set (+), find a different sentence in the training set that is closest to it in terms of sentence embedding. Does it make sense in terms of meaning and label? (0.5 pts)
2. For the second sentence in the training set (-), find a different sentence in the training set that is closest to it in terms of sentence embedding. Does it make sense in terms of meaning and label? (0.5 pts)
3. Report the error rates of k -NN classifier on dev for $k = 1, 3, \dots, 99$ using sentence embedding. You can reuse your code from HW1/HW2 and/or use `sklearn`. (0.75 pts) (should be $\sim 28\%$).
4. Report the error rates of k -NN classifier on dev for $k = 1, 3, \dots, 99$ using one-hot vectors from HW2. You can reuse your code from HWs 1-2 and/or use `sklearn`. (0.75 pts). (should be $\sim 40\%$).
5. Submit your best k -NN classifier to Kaggle and report the public error rate and ranking (take a screenshot). (0.5 pts) (should be $\sim 26\%$).

2.2 Reimplement Perceptron (3 pts)

Now that each sentence has an embedding, you can reimplement perceptron and average perceptron.

1. For basic perceptron, show the training logs for 10 epochs. Compare your best dev error rate (should be $\sim 31\%$) with the one from HW2. (0.5 pts)
2. For averaged perceptron, show the training logs for 10 epochs. Compare your best dev error rate (should be $\sim 23\text{--}24\%$) with the one from HW2. (0.5 pts)
3. Do you need to use smart averaging here? (0.25 pts)
4. For averaged perceptron after pruning one-count words, show the training logs for 10 epochs. Compare your dev error rate (should be $\sim 23.5\%$) with the one from HW2. (0.5 pts)
5. For the above setting, give at least two examples on dev where using features of `word2vec` is correct but using one-hot representation is wrong, and explain why. (0.75 pts)
6. Submit your averaged perceptron models (both with and without pruning) to Kaggle, and record best your public error rate and ranking (take a screenshot). (0.5 pts) (should be $\sim 22.4\%$)

2.3 Summarize the error rates in this table (0.5 pts)

	one-hot, best dev	embedding, best dev	best kaggle public
k -NN			
perceptron			

3 Try some other learning algorithms with sklearn (1.5 pts)

Now please try **one** other machine learning algorithm of your choice (either covered or not covered in our course) using **sklearn** (so that you don't need to implement them), such as k -NN, SVM, logistic regression, neural networks, decision trees, XGBoost, etc. To use **sklearn**, you will need to convert an **svector** object to a numpy vector. Note that this training might take a very long time, so you should prune one-count (and possibly two-count) words first. After pruning, the training might still take a long time. If you find it too slow, you can further prune more low-count words, and/or use a subset (e.g., 5,000) covered in the training set.

1. Which algorithm did you try? What adaptations did you make to your code to make it work with that algorithm? (0.5 pts)
2. What's the dev error rate(s) and running time? (0.5 pts)
3. What did you learn in terms of the comparison between averaged perceptron and these other (presumably more popular and well-known) learning algorithms? (0.5 pts)

4 Deployment (2 pts)

1. What's your best error rate on dev, and which algorithm and setting achieved it? (0.25 pts)
2. What's your best public error rate on Kaggle, and which algorithm and setting achieved it? (0.25 pts)

Part of your grade depends on your public and private error rates (1.5 pts). For example, our TA got 21%.

5 Debriefing (required):

1. Approximately how many hours did you spend on this assignment?
2. Would you rate it as easy, moderate, or difficult?
3. Did you work on it mostly alone, or mostly with other people?
4. How deeply do you feel you understand the material it covers (0%–100%)?
5. Any other comments?