baseline_naive_bayes

February 20, 2026

1 Data Preparation

Pipeline: Data Preparation -> Feature Encoding -> Training Phase -> Prediction Phase -> Evaluation

1.1 Setup

[ ]:
```
import nltk
from nltk.corpus import brown
import numpy as np
import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt
```

1.2 Data Discovery

Load Dataset

[ ]:
```
nltk.download('brown')
nltk.download('universal_tagset')
tagged_sents = brown.tagged_sents(tagset='universal')
```

```
[nltk_data] Downloading package brown to /root/nltk_data…
[nltk_data]   Unzipping corpora/brown.zip.
[nltk_data] Downloading package universal_tagset to /root/nltk_data…
[nltk_data]   Unzipping taggers/universal_tagset.zip.
```

[ ]:
```
print(tagged_sents[0])
```

```
[('The', 'DET'), ('Fulton', 'NOUN'), ('County', 'NOUN'), ('Grand', 'ADJ'),
('Jury', 'NOUN'), ('said', 'VERB'), ('Friday', 'NOUN'), ('an', 'DET'),
('investigation', 'NOUN'), ('of', 'ADP'), ("Atlanta's", 'NOUN'), ('recent',
'ADJ'), ('primary', 'NOUN'), ('election', 'NOUN'), ('produced', 'VERB'), ('``',
'.'), ('no', 'DET'), ('evidence', 'NOUN'), ("''", '.'), ('that', 'ADP'), ('any',
'DET'), ('irregularities', 'NOUN'), ('took', 'VERB'), ('place', 'NOUN'), ('.',
'.')]
```

Flatten all sentences into a list of (word, tag) tuples

[ ]:
```
data = [(word, tag) for sent in tagged_sents for word, tag in sent]
```

Convert data array into pandas dataframe

[ ]:
```
df = pd.DataFrame(data, columns=['word', 'tag'])
```

[ ]:
```
df.head()
```

[ ]:
```
      word   tag
0      The   DET
1   Fulton  NOUN
2   County  NOUN
3    Grand   ADJ
4     Jury  NOUN
```

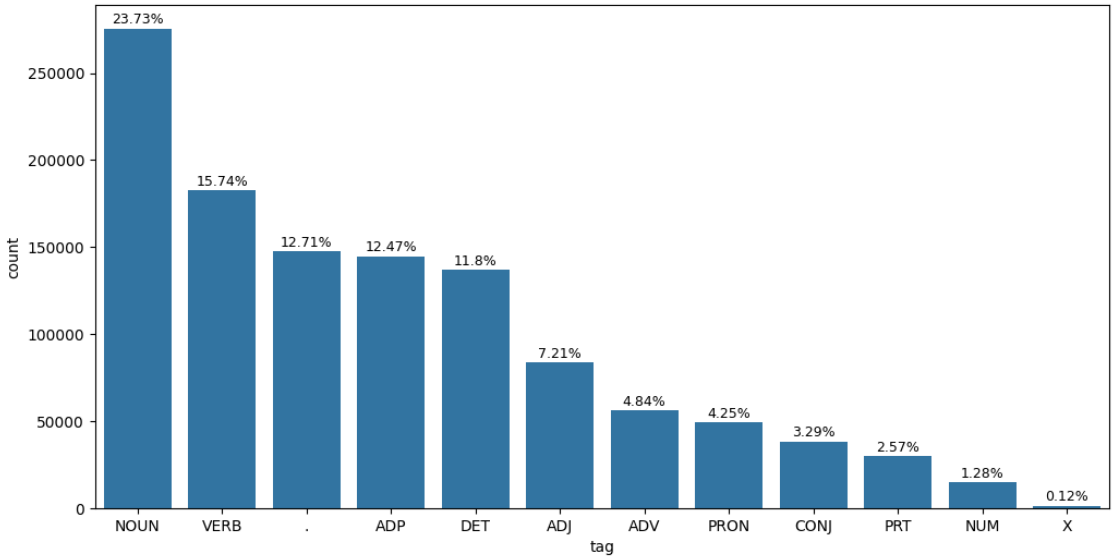
[ ]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1161192 entries, 0 to 1161191
Data columns (total 2 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   word    1161192 non-null  object
 1   tag     1161192 non-null  object
dtypes: object(2)
memory usage: 17.7+ MB
```

[ ]:
```
df['tag'].unique()
```

[ ]:
```
array(['DET', 'NOUN', 'ADJ', 'VERB', 'ADP', '.', 'ADV', 'CONJ', 'PRT',
       'PRON', 'NUM', 'X'], dtype=object)
```

[ ]:
```
tag_counts = df['tag'].value_counts()
tag_percentages = (tag_counts / len(df) * 100).round(2)

plt.figure(figsize=(12, 6))
ax = sns.countplot(df, x='tag', order=df['tag'].value_counts().index)

for i, (count, pct) in enumerate(zip(tag_counts.values, tag_percentages.
 ↪values)):
    ax.text(i, count + 1000, f'{pct}%', ha='center', va='bottom', fontsize=9)
```



2 Data Preprocessing

2.1 Feature Engineering

For each sentence in the data, add **context** to every single word:

- `sentence_id`: indicates which sentence a specified word is part of
- `word`: the current word
- `prev_word`: the previous word; 'BOS' refers to 'before of sentence'
- `next_word`: the next word; 'EOS' refers to 'end of sentence'

[ ]:
```
data = []
for sent_id, sent in enumerate(tagged_sents):
    for position, (word, tag) in enumerate(sent):
        # Get previous and next words for context
        prev_word = sent[position-1][0] if position > 0 else '<BOS>'
        next_word = sent[position+1][0] if position < len(sent)-1 else '<EOS>'

        data.append({
            'sentence_id': sent_id,
            'word': word.lower(),
            'prev_word': prev_word.lower(),
            'next_word': next_word.lower(),
            'tag': tag
        })
```

[ ]:
```
df = pd.DataFrame(data)
# First sentence
df[df['sentence_id'] == 0]
```

[ ]:

	sentence_id	word	prev_word	next_word	tag
0	0	the	<bos>	fulton	DET
1	0	fulton	the	county	NOUN
2	0	county	fulton	grand	NOUN
3	0	grand	county	jury	ADJ
4	0	jury	grand	said	NOUN
5	0	said	jury	friday	VERB
6	0	friday	said	an	NOUN
7	0	an	friday	investigation	DET
8	0	investigation	an	of	NOUN
9	0	of	investigation	atlanta's	ADP
10	0	atlanta's	of	recent	NOUN
11	0	recent	atlanta's	primary	ADJ
12	0	primary	recent	election	NOUN
13	0	election	primary	produced	NOUN
14	0	produced	election	``	VERB
15	0	``	produced	no	.
16	0	no	``	evidence	DET
17	0	evidence	no	''	NOUN
18	0	''	evidence	that	.
19	0	that	''	any	ADP
20	0	any	that	irregularities	DET
21	0	irregularities	any	took	NOUN
22	0	took	irregularities	place	VERB
23	0	place	took	.	NOUN
24	0	.	place	<eos>	.

2.2 Train Test Split (80% 20%)

[ ]:
```
from sklearn.model_selection import train_test_split
```

Split by sentence to avoid leakage

[ ]:
```
unique_sentences = df['sentence_id'].unique()
train_sents, test_sents = train_test_split(unique_sentences, test_size=0.2,␣
↪random_state=42)

train_df = df[df['sentence_id'].isin(train_sents)].reset_index(drop=True)
test_df = df[df['sentence_id'].isin(test_sents)].reset_index(drop=True)
```

[ ]:
```
print(train_df.shape)
print(test_df.shape)
```

```
(929265, 5)
```

```
(231927, 5)
```

2.3 Feature Encoding

[ ]:
```
from sklearn.preprocessing import LabelEncoder
```

Separate encoders for each feature

[ ]:
```
word_encoder = LabelEncoder()
prev_encoder = LabelEncoder()
next_encoder = LabelEncoder()
tag_encoder = LabelEncoder()
```

Fit training data into encoder

[ ]:
```
word_encoder.fit(train_df['word'].tolist() + ['<UNK>'])
prev_encoder.fit(train_df['prev_word'].tolist() + ['<UNK>'])
next_encoder.fit(train_df['next_word'].tolist() + ['<UNK>'])
tag_encoder.fit(train_df['tag'])
```

[ ]:
```
LabelEncoder()
```

[ ]:
```
print(word_encoder.classes_)
print(prev_encoder.classes_)
print(next_encoder.classes_)
print(tag_encoder.classes_)
```

```
['!' '$.027' '$.03' … 'zurich' 'zworykin' '{0,t}']
['!' '$.027' '$.03' … 'zurich' 'zworykin' '{0,t}']
['!' '$.027' '$.03' … 'zurich' 'zworykin' '{0,t}']
['.' 'ADJ' 'ADP' 'ADV' 'CONJ' 'DET' 'NOUN' 'NUM' 'PRON' 'PRT' 'VERB' 'X']
```

Helper function to transform encoder into array

[ ]:
```
def transform_helper(encoder, data):

    word_to_id = {word: idx for idx, word in enumerate(encoder.classes_)}
    unk_id = word_to_id['<UNK>']

    result = np.array([word_to_id.get(item, unk_id) for item in data])

    return result
```

Transform features and label; stack features for model fitting

[ ]:
```
word_train = transform_helper(word_encoder, train_df['word'])
prev_train = transform_helper(prev_encoder, train_df['prev_word'])
next_train = transform_helper(next_encoder, train_df['next_word'])

X_train = np.column_stack([word_train, prev_train, next_train])
```

```
y_train = tag_encoder.transform(train_df['tag'])
```

[ ]:
```
print(X_train.shape)
print(y_train.shape)
```

```
(929265, 3)
(929265,)
```

Label Encode Test Data

[ ]:
```
word_test = transform_helper(word_encoder, test_df['word'])
prev_test = transform_helper(prev_encoder, test_df['prev_word'])
next_test = transform_helper(next_encoder, test_df['next_word'])

X_test = np.column_stack([word_test, prev_test, next_test])
y_test = tag_encoder.transform(test_df['tag'])
```

[ ]:
```
print(X_test.shape)
print(y_test.shape)
```

```
(231927, 3)
(231927,)
```

3 Training Phase

[ ]:
```
from sklearn.naive_bayes import CategoricalNB
import time
```

[ ]:
```
nb = CategoricalNB()
training_start = time.perf_counter()
nb.fit(X_train, y_train)
training_end = time.perf_counter()
training_time = training_end - training_start
print(f'Training time: {training_time:.4f} seconds')
```

```
Training time: 0.7890 seconds
```

4 Prediction Phase

[ ]:
```
inference_start = time.perf_counter()
y_pred = nb.predict(X_test)
inference_end = time.perf_counter()
inference_time = inference_end - inference_start
print(f'Inference time: {inference_time:.4f} seconds')
```

```
Inference time: 0.1373 seconds
```

Classification Report

[ ]:
```
from sklearn.metrics import classification_report

labels = tag_encoder.classes_
print(classification_report(y_true=y_test, y_pred=y_pred, target_names=labels))
```

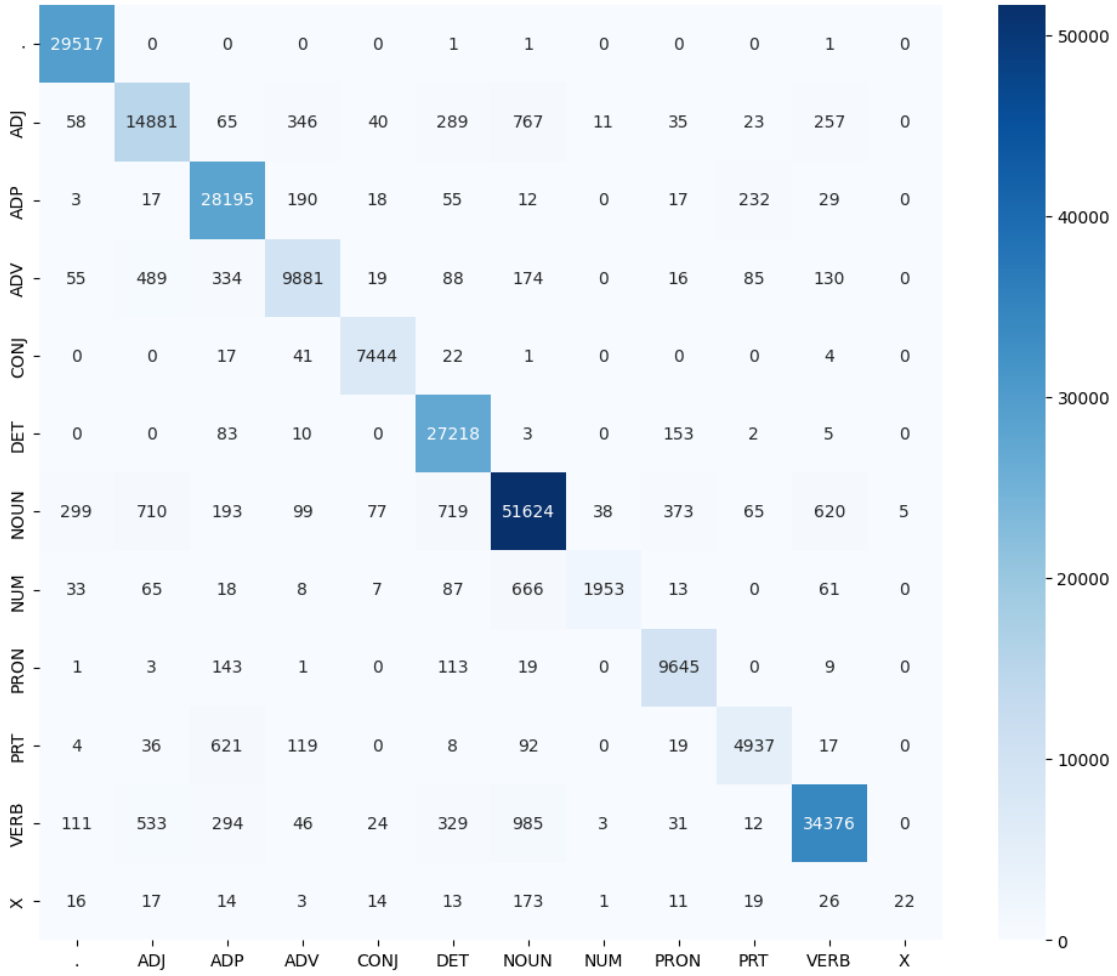
```
              precision    recall  f1-score   support

           .       0.98      1.00      0.99     29520
         ADJ       0.89      0.89      0.89     16772
         ADP       0.94      0.98      0.96     28768
         ADV       0.92      0.88      0.90     11271
        CONJ       0.97      0.99      0.98      7529
         DET       0.94      0.99      0.96     27474
        NOUN       0.95      0.94      0.94     54822
         NUM       0.97      0.67      0.79      2911
        PRON       0.94      0.97      0.95      9934
         PRT       0.92      0.84      0.88      5853
        VERB       0.97      0.94      0.95     36744
           X       0.81      0.07      0.12       329

    accuracy                           0.95    231927
   macro avg       0.93      0.85      0.86    231927
weighted avg       0.95      0.95      0.95    231927
```

Confusion Matrix

[ ]:
```
from sklearn.metrics import confusion_matrix
```

[ ]:
```
cm = confusion_matrix(y_true=y_test, y_pred=y_pred)
plt.figure(figsize=(12, 10))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=labels,␣
 ↪yticklabels=labels)
```

[ ]:
```
<Axes: >
```


. 29517 0 0 0 0 1 1 0 0 0 1 0
ADJ 58 14881 65 346 40 289 767 11 35 23 257 0
ADP 3 17 28195 190 18 55 12 0 17 232 29 0
ADV 55 489 334 9881 19 88 174 0 16 85 130 0
CONJ 0 0 17 41 7444 22 1 0 0 0 4 0
DET 0 0 83 10 0 27218 3 0 153 2 5 0
NOUN 299 710 193 99 77 719 51624 38 373 65 620 5
NUM 33 65 18 8 7 87 666 1953 13 0 61 0
PRON 1 3 143 1 0 113 19 0 9645 0 9 0
PRT 4 36 621 119 0 8 92 0 19 4937 17 0
VERB 111 533 294 46 24 329 985 3 31 12 34376 0
X 16 17 14 3 14 13 173 1 11 19 26 22
. ADJ ADP ADV CONJ DET NOUN NUM PRON PRT VERB X
50000
40000
30000
20000
10000
0