In [1]:
```
from utils.data import Dataset
from utils.conllu import read_conllu_dataset
import numpy as np
```

In [2]:
```
dataset = Dataset()

train_sentences = read_conllu_dataset("data/ro_rrt-ud-train.conllu")
test_sentences = read_conllu_dataset("data/ro_rrt-ud-test.conllu")

# Fit on training data
X_train, y_train = dataset.fit(train_sentences, mode="chars")

# Encode test data (fixed shape)
X_test, y_test = dataset.encode(test_sentences)
```

In [3]:
```
X_train.shape, y_train.shape, X_test.shape, y_test.shape
```

Out[3]:
```
((8043, 163, 55), (8043, 163, 17), (729, 163, 55), (729, 163, 17))
```

In [4]:
```
import tensorflow as tf
```

In [5]:
```
_, seq_len, char_feat_len = X_train.shape
output_dim = y_train.shape[-1]
```

In [6]:
```
sample_weight = np.where(np.argmax(y_train, axis=-1) != 0, 1.0, 0.0)
```

In [7]:
```
input_layer = tf.keras.layers.Input(shape=(seq_len, char_feat_len))
#lstm = tf.keras.layers.LSTM(256, return_sequences=True)(input_layer)
x = tf.keras.layers.Conv1D(64, kernel_size=(11,), padding="same")(input_layer)
x = tf.keras.layers.Conv1D(128, kernel_size=(7,), padding="same")(x)
x = tf.keras.layers.Conv1D(256, kernel_size=(3,), padding="same")(x)
output_layer = tf.keras.layers.TimeDistributed(tf.keras.layers.Dense(output_dim, activation='softmax'))(x)

model = tf.keras.models.Model(inputs=input_layer, outputs=output_layer)
model.compile(optimizer=tf.keras.optimizers.Adam(0.001), loss='categorical_crossentropy', weighted_metrics=['accuracy'])

model.summary()
```

Model: "functional"

Layer (type)	Output Shape	Param #
input_layer (InputLayer)	(None, 163, 55)	0
conv1d (Conv1D)	(None, 163, 64)	38,784
conv1d_1 (Conv1D)	(None, 163, 128)	57,472
conv1d_2 (Conv1D)	(None, 163, 256)	98,560
time_distributed (TimeDistributed)	(None, 163, 17)	4,369

Total params: 199,185 (778.07 KB)

Trainable params: 199,185 (778.07 KB)

Non-trainable params: 0 (0.00 B)

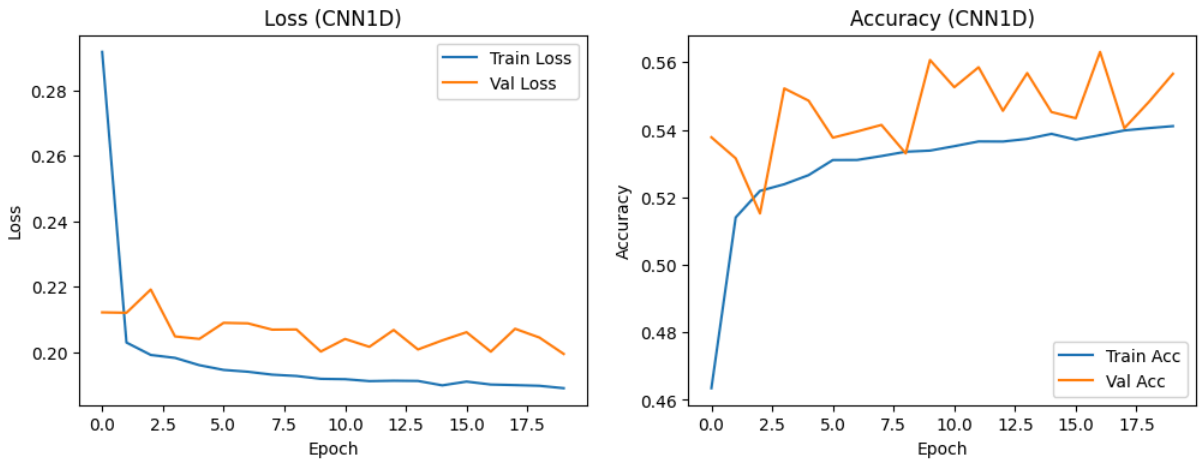
In [8]:
```
history = model.fit(
    X_train, y_train,
    validation_split=0.1,
    epochs=20,
    batch_size=64,
    sample_weight = sample_weight
)
```

```
Epoch 1/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 110s 834ms/step - accuracy: 0.3932 - loss: 0.4609 - val_accuracy: 0.5378 - val_loss: 0.2121
Epoch 2/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 94s 825ms/step - accuracy: 0.5109 - loss: 0.2023 - val_accuracy: 0.5315 - val_loss: 0.2120
Epoch 3/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 97s 849ms/step - accuracy: 0.5172 - loss: 0.1989 - val_accuracy: 0.5152 - val_loss: 0.2191
Epoch 4/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 139s 825ms/step - accuracy: 0.5189 - loss: 0.2008 - val_accuracy: 0.5522 - val_loss: 0.2047
Epoch 5/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 97s 850ms/step - accuracy: 0.5234 - loss: 0.1977 - val_accuracy: 0.5486 - val_loss: 0.2040
Epoch 6/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 96s 843ms/step - accuracy: 0.5291 - loss: 0.1970 - val_accuracy: 0.5376 - val_loss: 0.2089
Epoch 7/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 94s 826ms/step - accuracy: 0.5287 - loss: 0.1928 - val_accuracy: 0.5395 - val_loss: 0.2088
Epoch 8/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 94s 828ms/step - accuracy: 0.5318 - loss: 0.1937 - val_accuracy: 0.5414 - val_loss: 0.2068
Epoch 9/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 96s 841ms/step - accuracy: 0.5304 - loss: 0.1920 - val_accuracy: 0.5330 - val_loss: 0.2069
Epoch 10/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 137s 793ms/step - accuracy: 0.5331 - loss: 0.1916 - val_accuracy: 0.5606 - val_loss: 0.2001
Epoch 11/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 94s 823ms/step - accuracy: 0.5367 - loss: 0.1932 - val_accuracy: 0.5526 - val_loss: 0.2040
Epoch 12/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 138s 788ms/step - accuracy: 0.5357 - loss: 0.1921 - val_accuracy: 0.5585 - val_loss: 0.2016
Epoch 13/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 144s 802ms/step - accuracy: 0.5363 - loss: 0.1912 - val_accuracy: 0.5456 - val_loss: 0.2067
Epoch 14/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 143s 805ms/step - accuracy: 0.5345 - loss: 0.1927 - val_accuracy: 0.5568 - val_loss: 0.2008
Epoch 15/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 142s 799ms/step - accuracy: 0.5367 - loss: 0.1892 - val_accuracy: 0.5452 - val_loss: 0.2035
Epoch 16/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 92s 806ms/step - accuracy: 0.5352 - loss: 0.1925 - val_accuracy: 0.5434 - val_loss: 0.2060
Epoch 17/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 94s 822ms/step - accuracy: 0.5374 - loss: 0.1919 - val_accuracy: 0.5630 - val_loss: 0.2001
Epoch 18/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 95s 835ms/step - accuracy: 0.5411 - loss: 0.1915 - val_accuracy: 0.5405 - val_loss: 0.2071
Epoch 19/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 95s 830ms/step - accuracy: 0.5389 - loss: 0.1897 - val_accuracy: 0.5482 - val_loss: 0.2044
Epoch 20/20
114/114 ━━━━━━━━━━━━━━━━━━━━ 92s 803ms/step - accuracy: 0.5404 - loss: 0.1889 - val_accuracy: 0.5566 - val_loss: 0.1994
```

In [9]:
```
import matplotlib.pyplot as plt
```

In [10]:
```
plt.figure(figsize=(12, 4))
plt.subplot(1, 2, 1)
plt.plot(history.history['loss'], label="Train Loss")
plt.plot(history.history['val_loss'], label="Val Loss")
plt.title("Loss (CNN1D)")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(history.history['accuracy'], label="Train Acc")
plt.plot(history.history['val_accuracy'], label="Val Acc")
plt.title("Accuracy (CNN1D)")
plt.xlabel("Epoch")
plt.ylabel("Accuracy")
plt.legend()
plt.show()
```



In [11]:
```
model.save('pos_cnn1d_model.keras')
```

In [12]:
```python
test_loss, test_acc = model.evaluate(X_test, y_test, sample_weight=np.where(np.argmax(y_test, axis=-1) != 0, 1.0, 0.0))
print(f"\nTest Loss: {test_loss:.4f} | Test Accuracy: {test_acc:.4f}")
```

```
23/23 ━━━━━━━━━━━━━━━━━━━━ 1s 35ms/step - accuracy: 0.5283 - loss: 0.1887

Test Loss: 0.1869 | Test Accuracy: 0.5373
```

In [13]:
```python
import numpy as np
y_pred = model.predict(X_test)
y_pred_ids = np.argmax(y_pred, axis=-1)
y_true_ids = np.argmax(y_test, axis=-1)

# Reverse label index
idx2label = {i: l for l, i in dataset.label2id.items()}

# Show sample predictions
for i in range(3):
    print(f"\n--- Sentence {i+1} ---")
    for j in range(seq_len):
        word_vec = X_test[i, j]
        if np.all(word_vec == 0): continue  # padding

        pred_label = idx2label.get(y_pred_ids[i, j]-1, "UNK")
        true_label = idx2label.get(y_true_ids[i, j]-1, "UNK")
        print(f"{j:2}: Pred: {pred_label:6} | True: {true_label}")
```

```
23/23 ━━━━━━━━━━━━━━━━━━━━ 6s 183ms/step

--- Sentence 1 ---
 0: Pred: INTJ   | True: INTJ
 1: Pred: PART   | True: PART
 2: Pred: PART   | True: SCONJ
 3: Pred: SCONJ  | True: SCONJ
 4: Pred: PART   | True: ADP
 5: Pred: PART   | True: PART
 6: Pred: PROPN  | True: ADV
 7: Pred: PART   | True: SCONJ
 8: Pred: ADJ    | True: ADJ
 9: Pred: INTJ   | True: INTJ
10: Pred: PROPN  | True: PROPN

--- Sentence 2 ---
 0: Pred: ADJ    | True: ADJ
 1: Pred: INTJ   | True: INTJ
 2: Pred: INTJ   | True: PART
 3: Pred: ADP    | True: SCONJ
 4: Pred: CCONJ  | True: CCONJ
 5: Pred: INTJ   | True: INTJ
 6: Pred: ADJ    | True: ADJ
 7: Pred: SCONJ  | True: INTJ
 8: Pred: ADJ    | True: <PAD>
 9: Pred: CCONJ  | True: ADJ
10: Pred: INTJ   | True: INTJ
11: Pred: AUX    | True: AUX
12: Pred: ADJ    | True: CCONJ
13: Pred: INTJ   | True: INTJ
14: Pred: SCONJ  | True: PART
15: Pred: ADJ    | True: PART
16: Pred: INTJ   | True: SCONJ
17: Pred: INTJ   | True: ADJ
18: Pred: ADJ    | True: PART
19: Pred: PROPN  | True: PROPN

--- Sentence 3 ---
 0: Pred: PART   | True: ADV
 1: Pred: ADV    | True: CCONJ
 2: Pred: SCONJ  | True: INTJ
 3: Pred: SCONJ  | True: ADJ
 4: Pred: ADJ    | True: NOUN
 5: Pred: INTJ   | True: INTJ
 6: Pred: PROPN  | True: PROPN
 7: Pred: INTJ   | True: ADP
 8: Pred: INTJ   | True: INTJ
 9: Pred: AUX    | True: AUX
10: Pred: INTJ   | True: SCONJ
11: Pred: ADJ    | True: ADJ
12: Pred: INTJ   | True: INTJ
13: Pred: ADJ    | True: ADJ
14: Pred: ADJ    | True: CCONJ
15: Pred: INTJ   | True: INTJ
16: Pred: ADJ    | True: ADJ
17: Pred: INTJ   | True: CCONJ
18: Pred: PART   | True: NOUN
19: Pred: ADJ    | True: INTJ
20: Pred: ADJ    | True: ADJ
21: Pred: INTJ   | True: INTJ
22: Pred: PROPN  | True: PROPN
```

In [14]:
```python
np.argmax(y_test, axis=-1)[0]
```

Out[14]:
```
array([ 8, 11, 15, 15,  3, 11,  4, 15,  2,  8, 13,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
        0,  0,  0,  0,  0,  0,  0,  0,  0,  0])
```

In [15]:
```
y_true_flat = y_true_ids.reshape((-1,))
y_pred_flat = y_pred_ids.reshape((-1,))
mask = (y_true_flat != 0)
y_true_flat = y_true_flat[mask]
y_pred_flat = y_pred_flat[mask]

np.max(y_true_flat), np.min(y_true_flat), np.max(y_pred_flat), np.min(y_pred_flat)

np.sum(y_true_flat==7), np.sum(y_pred_flat==7)
```

Out[15]:
```
(np.int64(6), np.int64(0))
```

In [16]:

```
from sklearn.metrics import confusion_matrix, classification_report
import seaborn as sns
from matplotlib.colors import LogNorm

# Compute confusion matrix
labels = dataset.labels
label_ids = list(range(len(labels)))

print("Classification Report:")
print(classification_report(y_true_flat, y_pred_flat, labels=label_ids, target_names=labels))

cm = confusion_matrix(y_true_flat, y_pred_flat, labels=label_ids)

# Plot with log scale
plt.figure(figsize=(12, 10))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', norm=LogNorm(vmin=1, vmax=cm.max()),
            xticklabels=labels, yticklabels=labels, cbar_kws={'label': 'Log-scaled count'})
plt.xlabel("Predicted")
plt.ylabel("True")
plt.title("Confusion Matrix (CNN1D)")
plt.tight_layout()
plt.show()
```

```
Classification Report:
              precision    recall  f1-score   support

       <PAD>       0.00      0.00      0.00         0
         ADJ       0.38      0.34      0.36      1172
         ADP       0.55      0.81      0.66      2333
         ADV       0.24      0.04      0.06       650
         AUX       0.41      0.29      0.34       618
       CCONJ       0.75      0.37      0.49       471
         DET       0.33      0.16      0.21       898
        INTJ       0.00      0.00      0.00         6
        NOUN       0.52      0.69      0.60      4042
         NUM       0.68      0.55      0.60       456
        PART       0.38      0.20      0.26       358
        PRON       0.23      0.23      0.23       862
       PROPN       0.58      0.55      0.57       455
       PUNCT       0.85      0.94      0.89      2083
       SCONJ       0.55      0.04      0.07       154
        VERB       0.37      0.24      0.30      1749
           X       0.56      0.29      0.38        17

    accuracy                           0.54     16324
   macro avg       0.43      0.34      0.35     16324
weighted avg       0.51      0.54      0.51     16324

d:\anu1m\sem2\NLP\soft\PoSTagging\.venv\lib\site-packages\sklearn\metrics\_classification.py:1565: UndefinedMetricWarning: Precision is i
ll-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
d:\anu1m\sem2\NLP\soft\PoSTagging\.venv\lib\site-packages\sklearn\metrics\_classification.py:1565: UndefinedMetricWarning: Recall is ill-
defined and being set to 0.0 in labels with no true samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
d:\anu1m\sem2\NLP\soft\PoSTagging\.venv\lib\site-packages\sklearn\metrics\_classification.py:1565: UndefinedMetricWarning: F-score is ill
-defined and being set to 0.0 in labels with no true nor predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
d:\anu1m\sem2\NLP\soft\PoSTagging\.venv\lib\site-packages\sklearn\metrics\_classification.py:1565: UndefinedMetricWarning: Precision is i
ll-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
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d:\anu1m\sem2\NLP\soft\PoSTagging\.venv\lib\site-packages\sklearn\metrics\_classification.py:1565: UndefinedMetricWarning: Recall is ill-
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  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
d:\anu1m\sem2\NLP\soft\PoSTagging\.venv\lib\site-packages\sklearn\metrics\_classification.py:1565: UndefinedMetricWarning: F-score is ill
-defined and being set to 0.0 in labels with no true nor predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

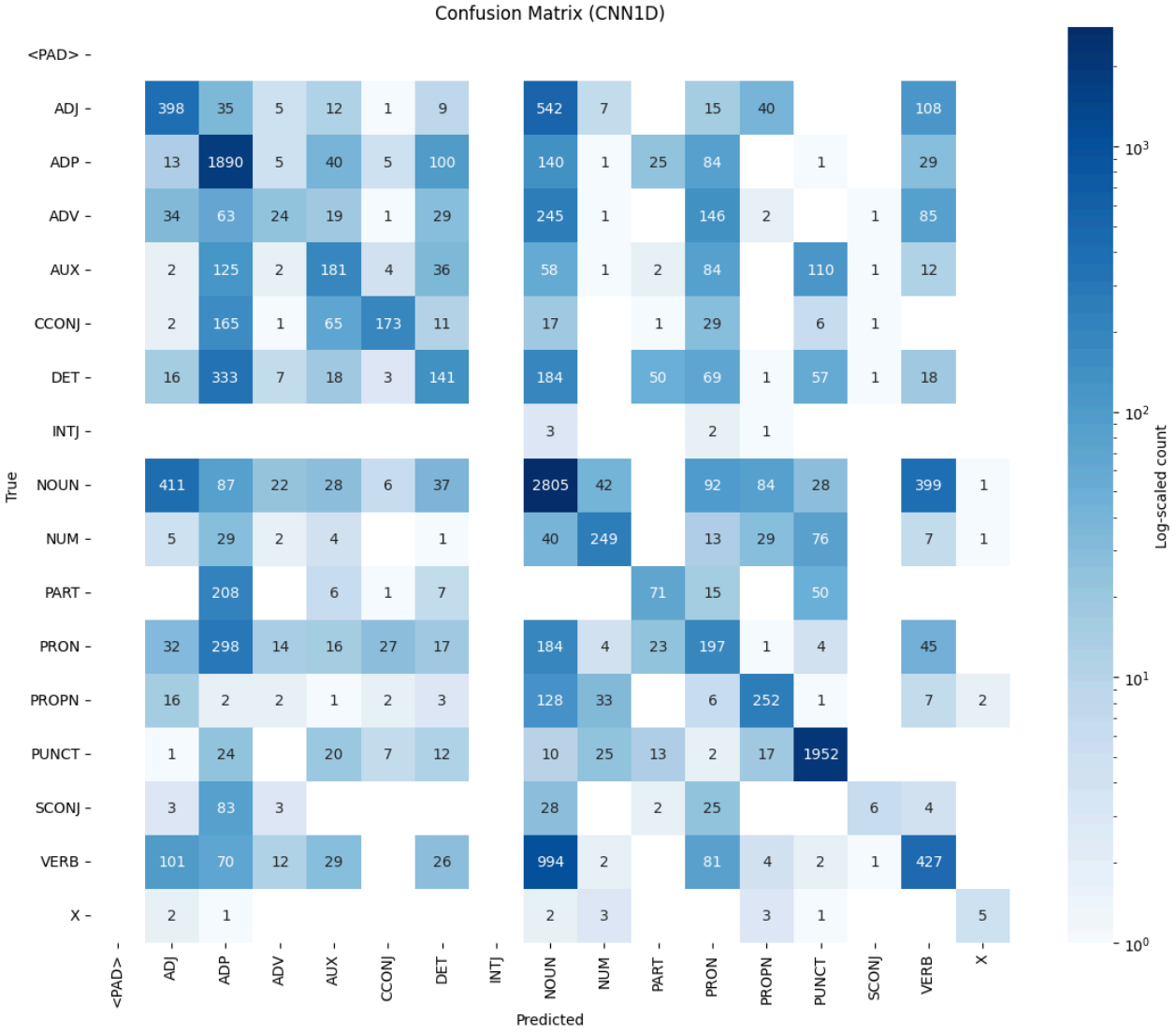
Confusion Matrix (CNN1D)
True
Predicted
Log-scaled count
<PAD>
ADJ
ADP
ADV
AUX
CCONJ
DET
INTJ
NOUN
NUM
PART
PRON
PROPN
PUNCT
SCONJ
VERB
X