CS7.501 | Advanced NLP| Assignment - 1

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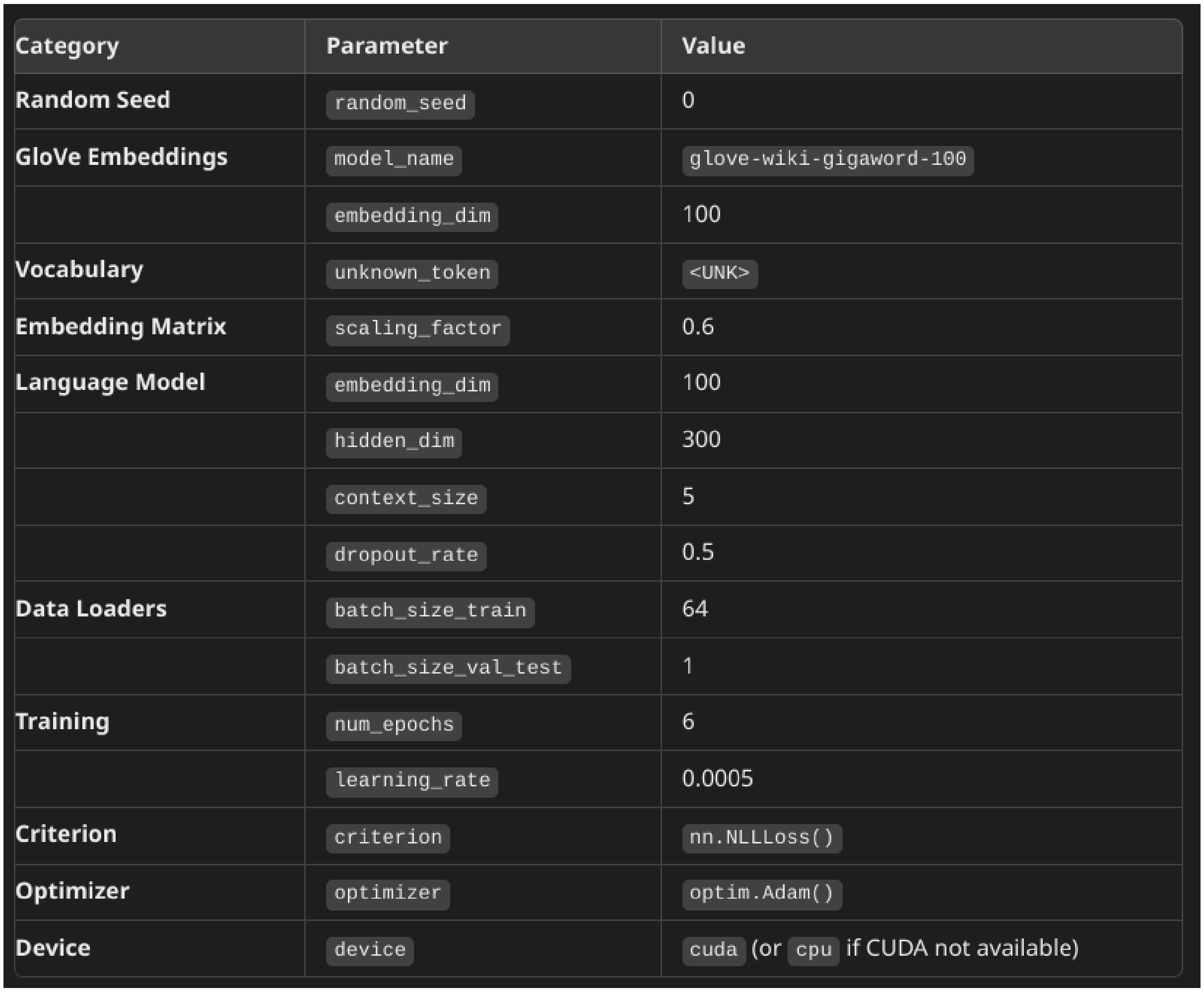
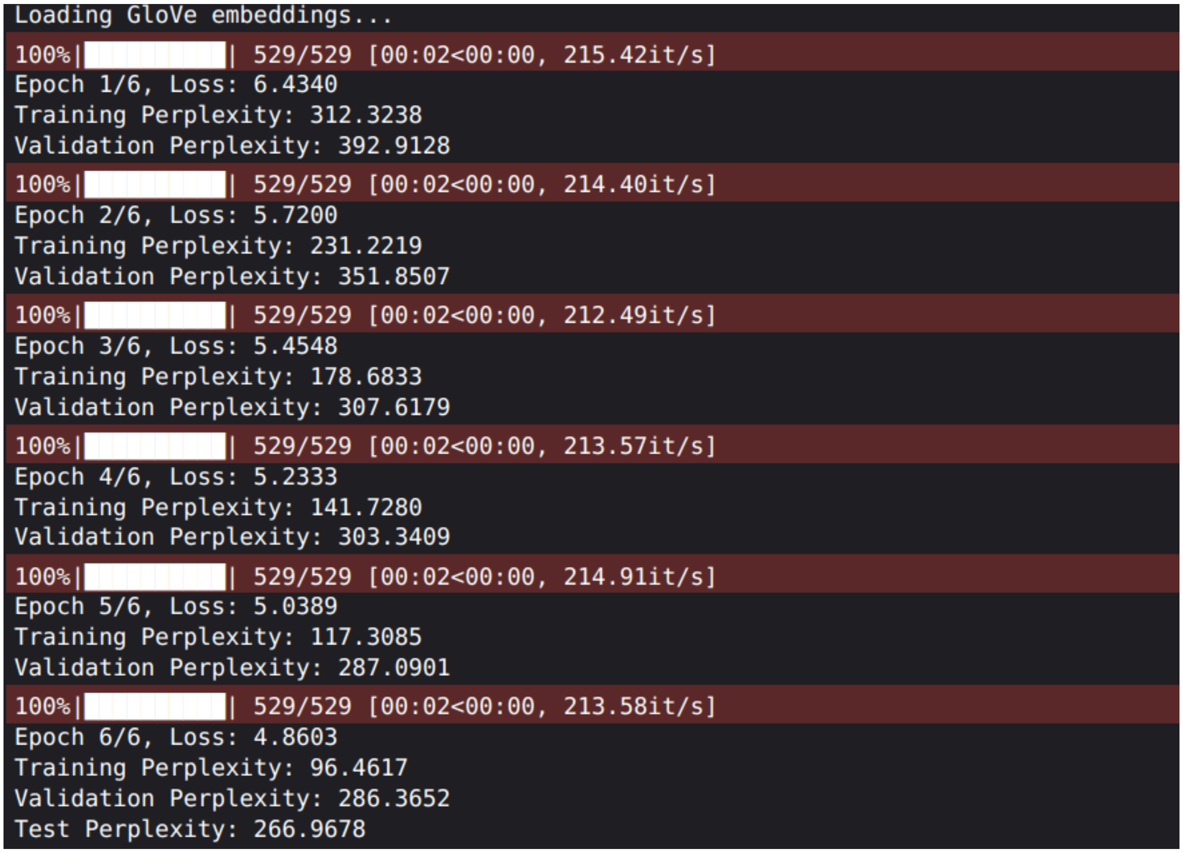
2023202005

1 Neural Network Language Model



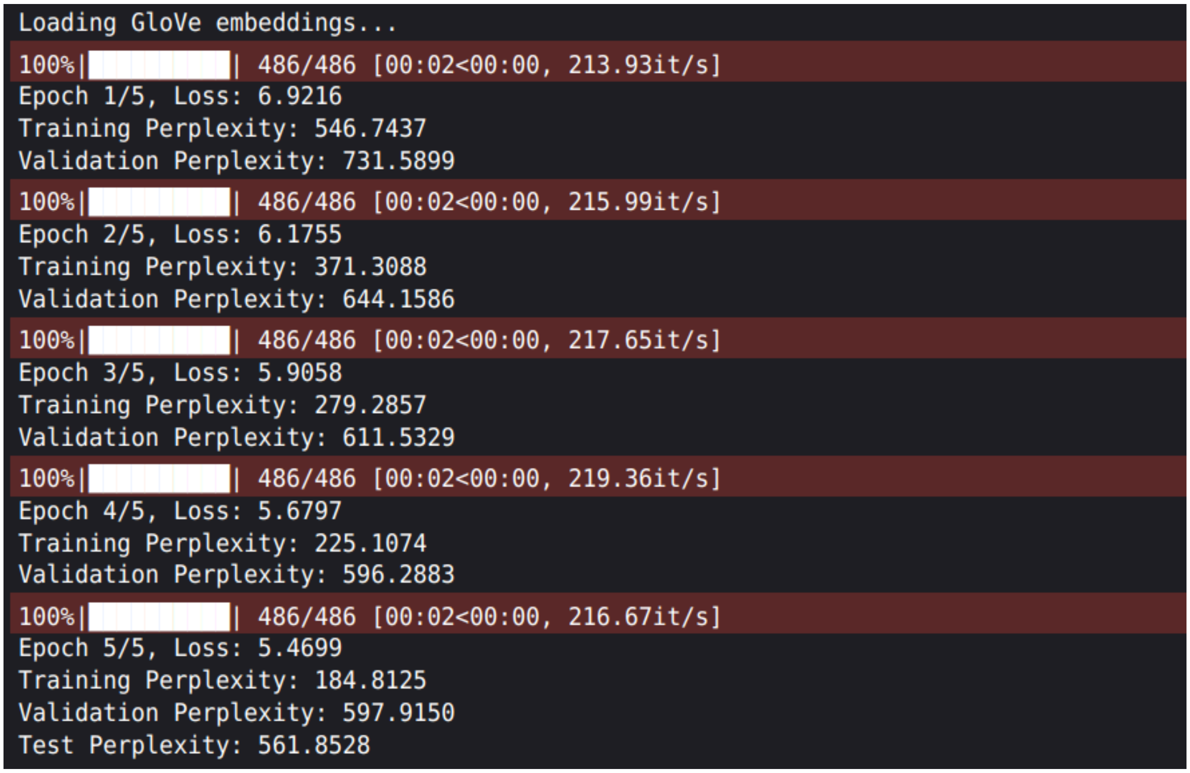
Category	Parameter	Value
Random Seed	`random_seed`	0
GloVe Embeddings	`model_name`	`glove-wiki-gigaword-100`
	`embedding_dim`	100
Vocabulary	`unknown_token`	`<UNK>`
Embedding Matrix	`scaling_factor`	0.6
Language Model	`embedding_dim`	100
	`hidden_dim`	300
	`context_size`	5
	`dropout_rate`	0.5
Data Loaders	`batch_size_train`	64
	`batch_size_val_test`	1
Training	`num_epochs`	6
	`learning_rate`	0.0005
Criterion	`criterion`	`nn.NLLLoss()`
Optimizer	`optimizer`	`optim.Adam()`
Device	`device`	`cuda` (or `cpu` if CUDA not available)

Without removing punctuations



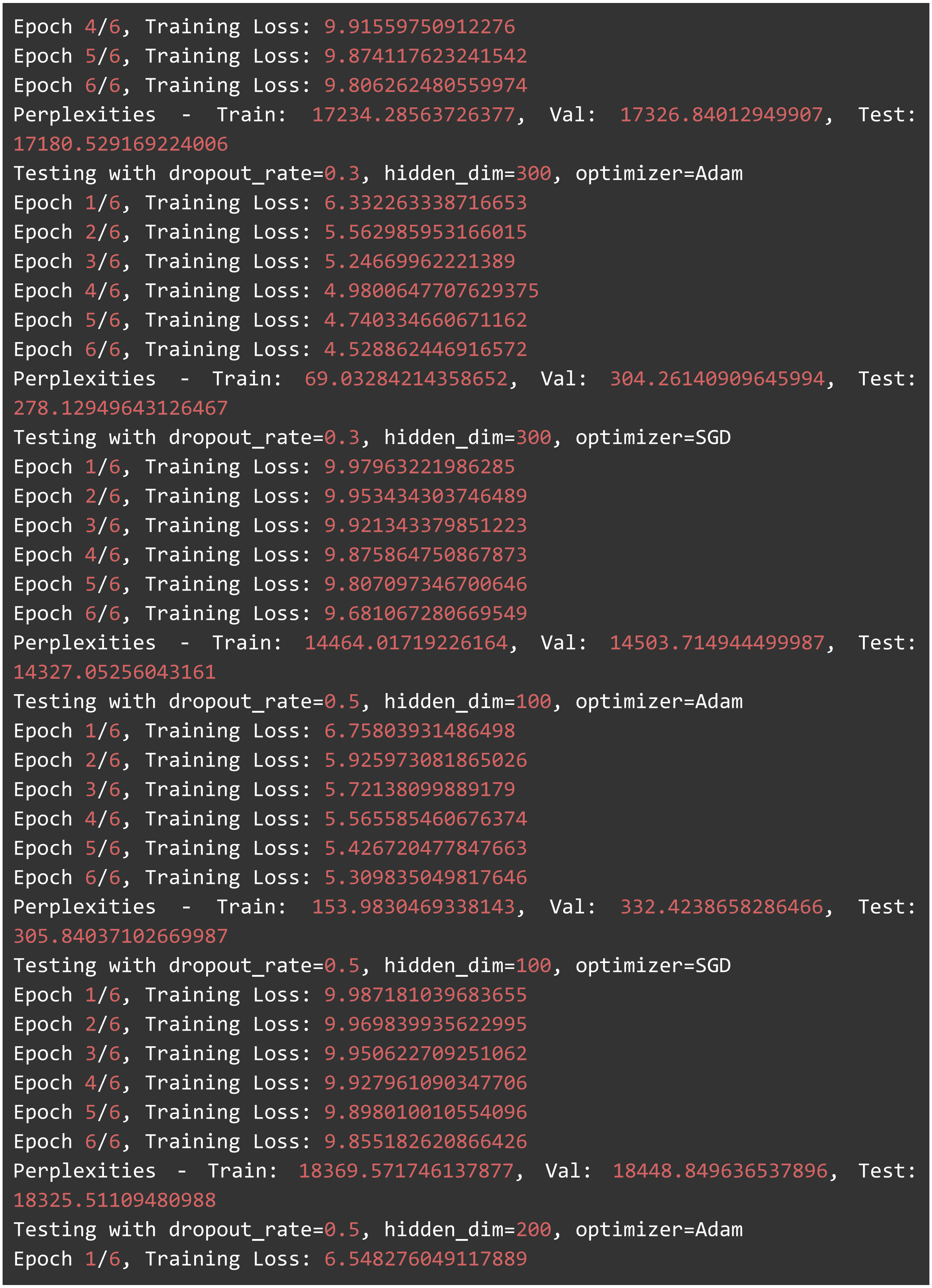
```
Loading GloVe embeddings...
100%|██████████| 529/529 [00:02<00:00, 215.42it/s]
Epoch 1/6, Loss: 6.4340
Training Perplexity: 312.3238
Validation Perplexity: 392.9128
100%|██████████| 529/529 [00:02<00:00, 214.40it/s]
Epoch 2/6, Loss: 5.7200
Training Perplexity: 231.2219
Validation Perplexity: 351.8507
100%|██████████| 529/529 [00:02<00:00, 212.49it/s]
Epoch 3/6, Loss: 5.4548
Training Perplexity: 178.6833
Validation Perplexity: 307.6179
100%|██████████| 529/529 [00:02<00:00, 213.57it/s]
Epoch 4/6, Loss: 5.2333
Training Perplexity: 141.7280
Validation Perplexity: 303.3409
100%|██████████| 529/529 [00:02<00:00, 214.91it/s]
Epoch 5/6, Loss: 5.0389
Training Perplexity: 117.3085
Validation Perplexity: 287.0901
100%|██████████| 529/529 [00:02<00:00, 213.58it/s]
Epoch 6/6, Loss: 4.8603
Training Perplexity: 96.4617
Validation Perplexity: 286.3652
Test Perplexity: 266.9678
```

With removing punctuations



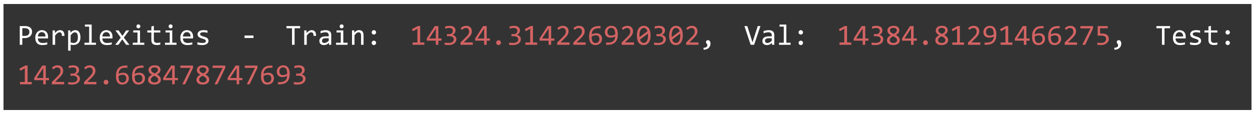
```
Loading GloVe embeddings...
100%|██████████| 486/486 [00:02<00:00, 213.93it/s]
Epoch 1/5, Loss: 6.9216
Training Perplexity: 546.7437
Validation Perplexity: 731.5899
100%|██████████| 486/486 [00:02<00:00, 215.99it/s]
Epoch 2/5, Loss: 6.1755
Training Perplexity: 371.3088
Validation Perplexity: 644.1586
100%|██████████| 486/486 [00:02<00:00, 217.65it/s]
Epoch 3/5, Loss: 5.9058
Training Perplexity: 279.2857
Validation Perplexity: 611.5329
100%|██████████| 486/486 [00:02<00:00, 219.36it/s]
Epoch 4/5, Loss: 5.6797
Training Perplexity: 225.1074
Validation Perplexity: 596.2883
100%|██████████| 486/486 [00:02<00:00, 216.67it/s]
Epoch 5/5, Loss: 5.4699
Training Perplexity: 184.8125
Validation Perplexity: 597.9150
Test Perplexity: 561.8528
```

```
Hyperparameter tuning

    dropout_rates = [0.3, 0.5, 0.6]
    hidden_dims = [100, 200, 300]
    optimizers = {
        'Adam': optim.Adam,
        'SGD': optim.SGD
    }

Loading GloVe embeddings...
Testing with dropout_rate=0.3, hidden_dim=100, optimizer=Adam
Epoch 1/6, Training Loss: 6.600046329807274
Epoch 2/6, Training Loss: 5.767457309958359
Epoch 3/6, Training Loss: 5.516558956194956
Epoch 4/6, Training Loss: 5.320902709830127
Epoch 5/6, Training Loss: 5.159758554277965
Epoch 6/6, Training Loss: 5.016563756141424
Perplexities - Train: 120.5487654006155, Val: 303.8639801481259, Test:
282.1146477715682
Testing with dropout_rate=0.3, hidden_dim=100, optimizer=SGD
Epoch 1/6, Training Loss: 9.987481632708544
Epoch 2/6, Training Loss: 9.966470156689125
Epoch 3/6, Training Loss: 9.944000297028559
Epoch 4/6, Training Loss: 9.915775954025609
Epoch 5/6, Training Loss: 9.87676782383625
Epoch 6/6, Training Loss: 9.817169153142006
Perplexities - Train: 17531.543225644044, Val: 17624.202125025873, Test:
17510.2149101477
Testing with dropout_rate=0.3, hidden_dim=200, optimizer=Adam
Epoch 1/6, Training Loss: 6.409498654063661
Epoch 2/6, Training Loss: 5.622801234286009
Epoch 3/6, Training Loss: 5.332954812644714
Epoch 4/6, Training Loss: 5.105601349691134
Epoch 5/6, Training Loss: 4.908686667423489
Epoch 6/6, Training Loss: 4.722426972181165
Perplexities - Train: 87.79817837652482, Val: 302.47431913479915, Test:
280.7662033190571
Testing with dropout_rate=0.3, hidden_dim=200, optimizer=SGD
Epoch 1/6, Training Loss: 9.987233916678806
Epoch 2/6, Training Loss: 9.967827401122289
Epoch 3/6, Training Loss: 9.946007439328154
```

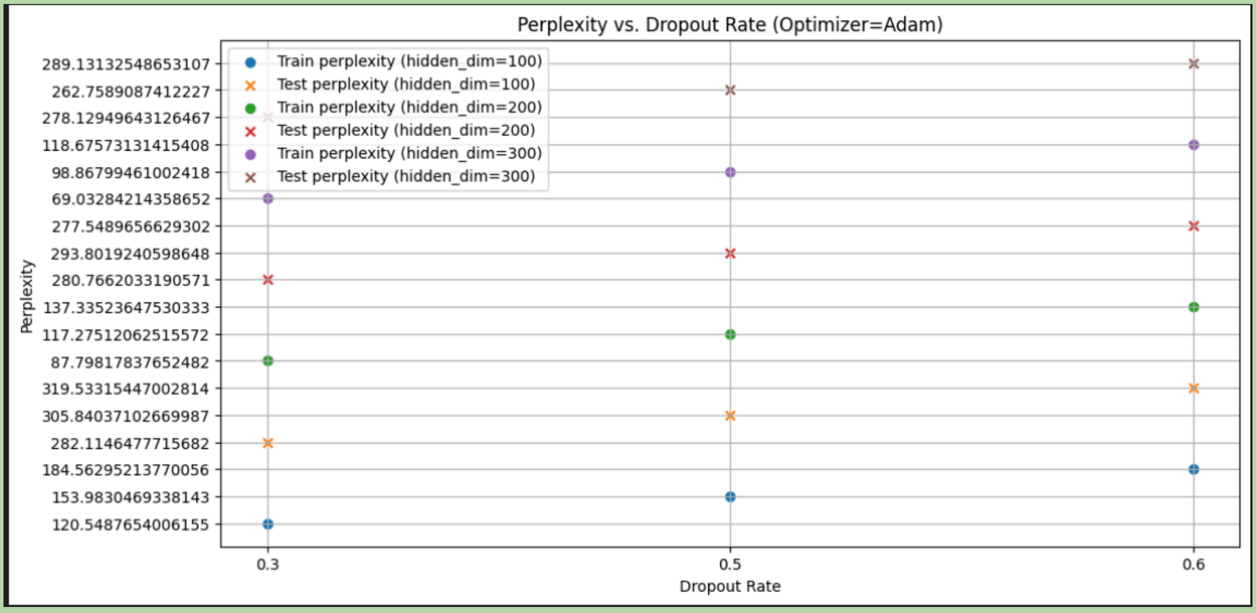


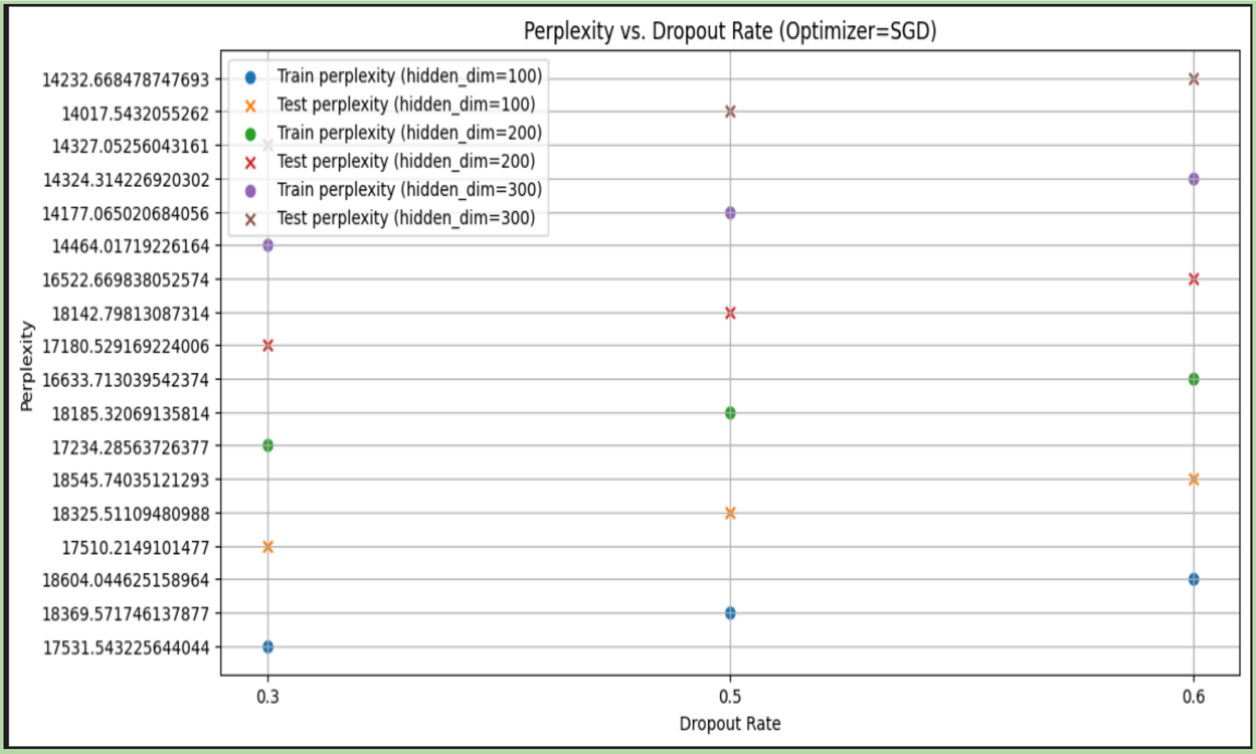
```
Epoch 4/6, Training Loss: 9.91559750912276
Epoch 5/6, Training Loss: 9.874117623241542
Epoch 6/6, Training Loss: 9.806262480559974
Perplexities - Train: 17234.28563726377, Val: 17326.84012949907, Test:
17180.529169224006
Testing with dropout_rate=0.3, hidden_dim=300, optimizer=Adam
Epoch 1/6, Training Loss: 6.332263338716653
Epoch 2/6, Training Loss: 5.562985953166015
Epoch 3/6, Training Loss: 5.24669962221389
Epoch 4/6, Training Loss: 4.9800647707629375
Epoch 5/6, Training Loss: 4.740334660671162
Epoch 6/6, Training Loss: 4.528862446916572
Perplexities - Train: 69.03284214358652, Val: 304.26140909645994, Test:
278.12949643126467
Testing with dropout_rate=0.3, hidden_dim=300, optimizer=SGD
Epoch 1/6, Training Loss: 9.97963221986285
Epoch 2/6, Training Loss: 9.953434303746489
Epoch 3/6, Training Loss: 9.921343379851223
Epoch 4/6, Training Loss: 9.875864750867873
Epoch 5/6, Training Loss: 9.807097346700646
Epoch 6/6, Training Loss: 9.681067280669549
Perplexities - Train: 14464.01719226164, Val: 14503.714944499987, Test:
14327.05256043161
Testing with dropout_rate=0.5, hidden_dim=100, optimizer=Adam
Epoch 1/6, Training Loss: 6.75803931486498
Epoch 2/6, Training Loss: 5.925973081865026
Epoch 3/6, Training Loss: 5.72138099889179
Epoch 4/6, Training Loss: 5.565585460676374
Epoch 5/6, Training Loss: 5.426720477847663
Epoch 6/6, Training Loss: 5.309835049817646
Perplexities - Train: 153.9830469338143, Val: 332.4238658286466, Test:
305.84037102669987
Testing with dropout_rate=0.5, hidden_dim=100, optimizer=SGD
Epoch 1/6, Training Loss: 9.987181039683655
Epoch 2/6, Training Loss: 9.969839935622995
Epoch 3/6, Training Loss: 9.950622709251062
Epoch 4/6, Training Loss: 9.927961090347706
Epoch 5/6, Training Loss: 9.898010010554096
Epoch 6/6, Training Loss: 9.855182620866426
Perplexities - Train: 18369.571746137877, Val: 18448.849636537896, Test:
18325.51109480988
Testing with dropout_rate=0.5, hidden_dim=200, optimizer=Adam
Epoch 1/6, Training Loss: 6.548276049117889
Epoch 2/6, Training Loss: 5.811249007087122
Epoch 3/6, Training Loss: 5.567389812877701
Epoch 4/6, Training Loss: 5.354703682061275
Epoch 5/6, Training Loss: 5.175198895663139
Epoch 6/6, Training Loss: 5.02356567886883
Perplexities - Train: 117.27512062515572, Val: 315.95460293982615, Test:
293.8019240598648
Testing with dropout_rate=0.5, hidden_dim=200, optimizer=SGD
Epoch 1/6, Training Loss: 10.000177319370941
Epoch 2/6, Training Loss: 9.979815910707428
Epoch 3/6, Training Loss: 9.959387696915602
Epoch 4/6, Training Loss: 9.933215921647134
Epoch 5/6, Training Loss: 9.899817611867547
Epoch 6/6, Training Loss: 9.848393470468258
Perplexities - Train: 18185.32069135814, Val: 18190.887855261488, Test:
18142.79813087314
Testing with dropout_rate=0.5, hidden_dim=300, optimizer=Adam
Epoch 1/6, Training Loss: 6.434789221859351
Epoch 2/6, Training Loss: 5.71839049105753
Epoch 3/6, Training Loss: 5.463090479141349
Epoch 4/6, Training Loss: 5.243058755181565
Epoch 5/6, Training Loss: 5.06012604932096
Epoch 6/6, Training Loss: 4.873657890029786
Perplexities - Train: 98.86799461002418, Val: 285.7722867824029, Test:
262.7589087412227
Testing with dropout_rate=0.5, hidden_dim=300, optimizer=SGD
Epoch 1/6, Training Loss: 9.986726173796919
Epoch 2/6, Training Loss: 9.957774633773186
Epoch 3/6, Training Loss: 9.924773318414868
Epoch 4/6, Training Loss: 9.877445147084586
Epoch 5/6, Training Loss: 9.80373771638612
Epoch 6/6, Training Loss: 9.673692627805647
Perplexities - Train: 14177.065020684056, Val: 14241.246892685176, Test:
14017.5432055262
Testing with dropout_rate=0.6, hidden_dim=100, optimizer=Adam
Epoch 1/6, Training Loss: 6.926044169224449
Epoch 2/6, Training Loss: 6.032343579026504
Epoch 3/6, Training Loss: 5.84534536970413
Epoch 4/6, Training Loss: 5.707752443056263
Epoch 5/6, Training Loss: 5.591725616121287
Epoch 6/6, Training Loss: 5.481440338778893
Perplexities - Train: 184.56295213770056, Val: 333.6098351136401, Test:
319.53315447002814
```

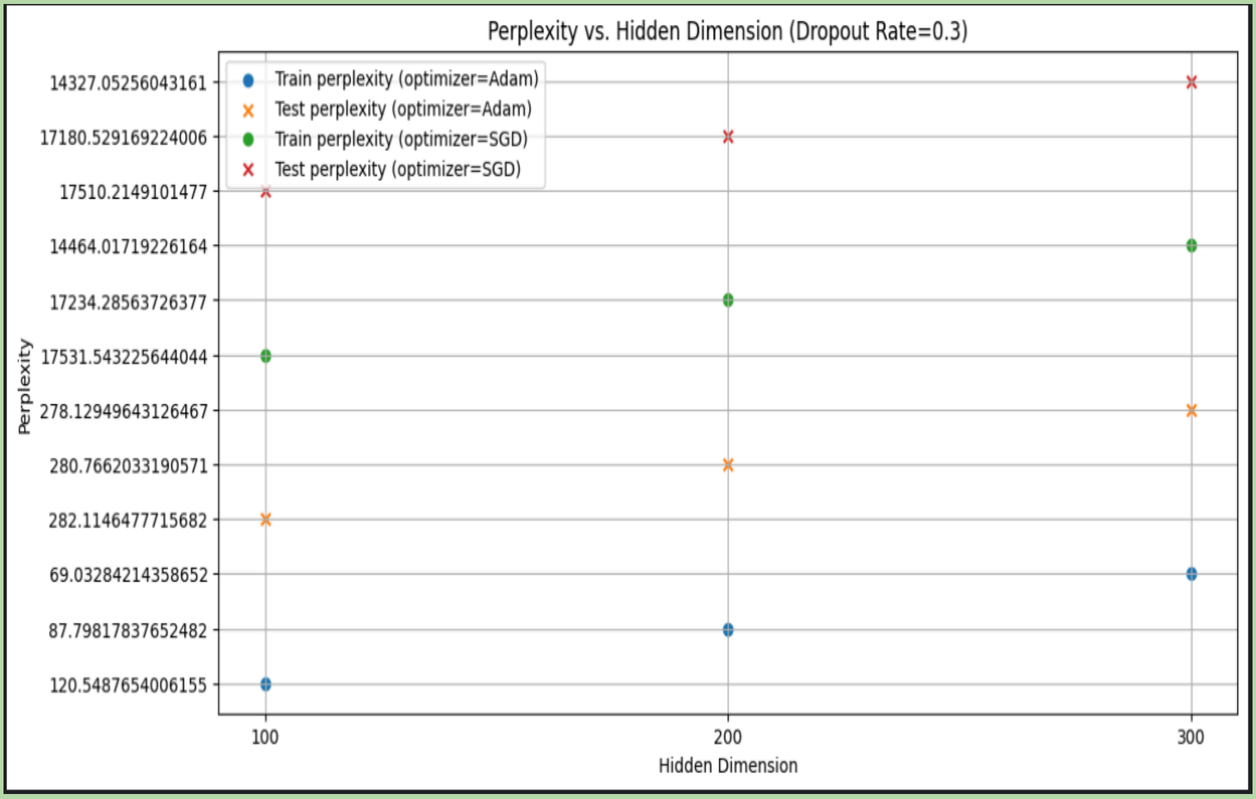
```
Testing with dropout_rate=0.6, hidden_dim=100, optimizer=SGD
Epoch 1/6, Training Loss: 9.989177842674152
Epoch 2/6, Training Loss: 9.973100799469432
Epoch 3/6, Training Loss: 9.956651562224668
Epoch 4/6, Training Loss: 9.93450682126871
Epoch 5/6, Training Loss: 9.906129370517196
Epoch 6/6, Training Loss: 9.867442151678924
Perplexities - Train: 18604.044625158964, Val: 18645.095970655766, Test:
18545.74035121293
Testing with dropout_rate=0.6, hidden_dim=200, optimizer=Adam
Epoch 1/6, Training Loss: 6.621975268936473
Epoch 2/6, Training Loss: 5.890680602471626
Epoch 3/6, Training Loss: 5.681389439623308
Epoch 4/6, Training Loss: 5.489405424357786
Epoch 5/6, Training Loss: 5.332885224415758
Epoch 6/6, Training Loss: 5.188972839695125
Perplexities - Train: 137.33523647530333, Val: 299.6685674957917, Test:
277.5489656629302
Testing with dropout_rate=0.6, hidden_dim=200, optimizer=SGD
Epoch 1/6, Training Loss: 9.975854239791396
Epoch 2/6, Training Loss: 9.954204902703054
Epoch 3/6, Training Loss: 9.929406823059818
Epoch 4/6, Training Loss: 9.898176892169953
Epoch 5/6, Training Loss: 9.853009580508662
Epoch 6/6, Training Loss: 9.781647579346028
Perplexities - Train: 16633.713039542374, Val: 16705.654900731955, Test:
16522.669838052574
Testing with dropout_rate=0.6, hidden_dim=300, optimizer=Adam
Epoch 1/6, Training Loss: 6.5212276369541184
Epoch 2/6, Training Loss: 5.820869155086298
Epoch 3/6, Training Loss: 5.591036766799218
Epoch 4/6, Training Loss: 5.396946949500402
Epoch 5/6, Training Loss: 5.2156815056937855
Epoch 6/6, Training Loss: 5.054351044670972
Perplexities - Train: 118.67573131415408, Val: 314.3033004767873, Test:
289.13132548653107
Testing with dropout_rate=0.6, hidden_dim=300, optimizer=SGD
Epoch 1/6, Training Loss: 9.976056820198592
Epoch 2/6, Training Loss: 9.948962996583099
Epoch 3/6, Training Loss: 9.917361500218952
Epoch 4/6, Training Loss: 9.872046566043352
Epoch 5/6, Training Loss: 9.804056232894892
Epoch 6/6, Training Loss: 9.680542918797629
```

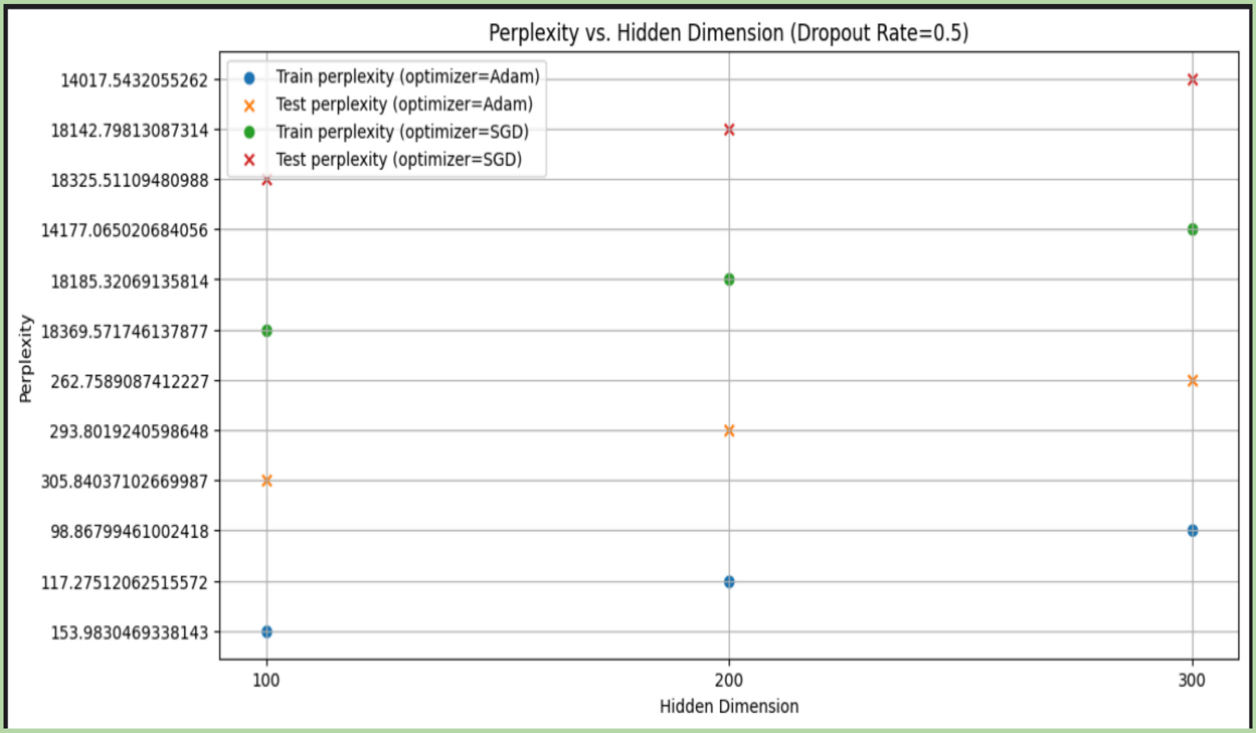


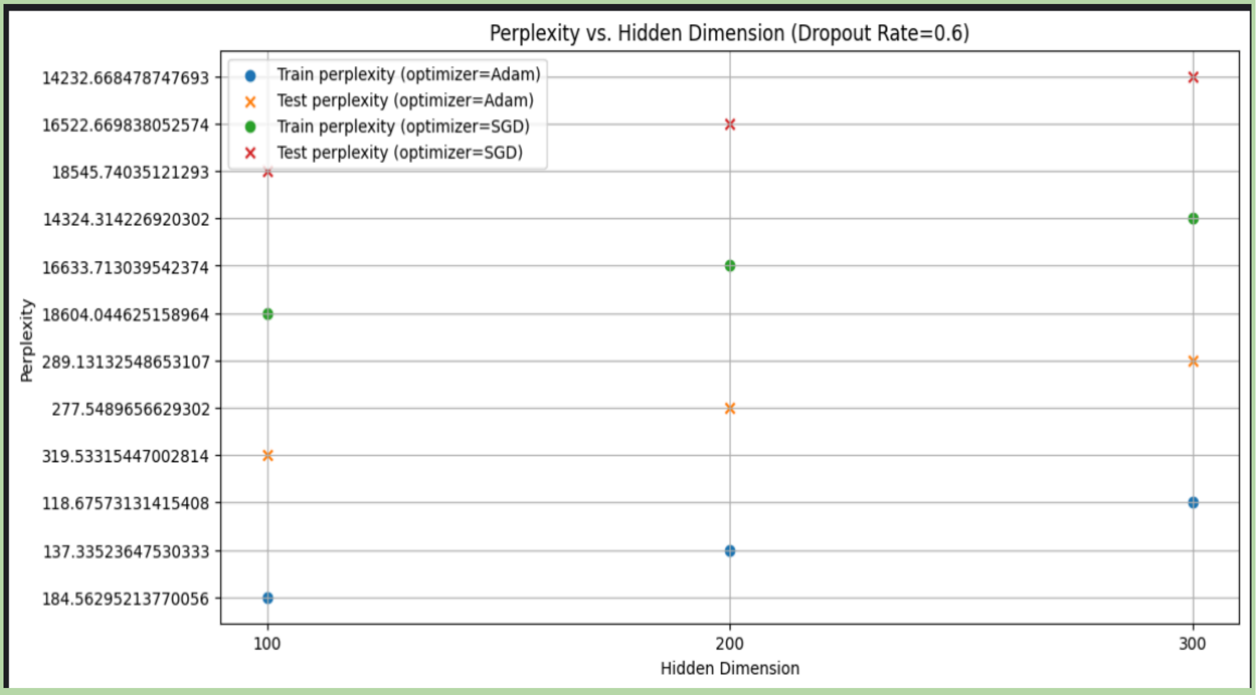
```
Perplexities  - Train:  14324.314226920302,  Val:  14384.81291466275,  Test:
14232.668478747693
```






Perplexity vs. Hidden Dimension (Dropout Rate=0.3)
● Train perplexity (optimizer=Adam)
× Test perplexity (optimizer=Adam)
● Train perplexity (optimizer=SGD)
× Test perplexity (optimizer=SGD)
Perplexity
14327.05256043161
17180.529169224006
17510.2149101477
14464.01719226164
17234.28563726377
17531.543225644044
278.12949643126467
280.7662033190571
282.1146477715682
69.03284214358652
87.79817837652482
120.5487654006155
100
200
300
Hidden Dimension


Perplexity vs. Hidden Dimension (Dropout Rate=0.5)
● Train perplexity (optimizer=Adam)
× Test perplexity (optimizer=Adam)
● Train perplexity (optimizer=SGD)
× Test perplexity (optimizer=SGD)
Perplexity
14017.5432055262
18142.79813087314
18325.51109480988
14177.065020684056
18185.32069135814
18369.571746137877
262.7589087412227
293.8019240598648
305.84037102669987
98.86799461002418
117.27512062515572
153.9830469338143
100
200
300
Hidden Dimension



Best hyperparameters

2 RNN-based Language Model

Parameter	Value
Embedding Dimension	100
Hidden Dimension	300
Dropout Rate	0.5
Batch Size (Training)	64
Batch Size (Validation)	1
Batch Size (Test)	1
Learning Rate	0.001
Number of Epochs	10
Sequence Length	40

```
class LanguageModelDataset(Dataset):
    def __init__(self, sentences, word_to_idx, seq_length=40):
        self.sentences = sentences
        self.word_to_idx = word_to_idx
        self.seq_length = seq_length
        self.data = self.prepare_data()

    def prepare_data(self):
        data = []
        pad_idx = self.word_to_idx["<PAD>"]
        for sentence in self.sentences:
                if len(sentence) > 1:  # Ensure the sentence has at least 2 words
                            indexed_sentence = [self.word_to_idx.get(word, self.word_to_idx["<UNK>"]) for word in sentence]

                # Pad or truncate the sentence to seq_length + 1
                if len(indexed_sentence) < self.seq_length + 1:
                        indexed_sentence = indexed_sentence + [pad_idx] * (self.seq_length + 1 - len(indexed_sentence))
                else:
                        indexed_sentence = indexed_sentence[:self.seq_length + 1]

                # Create input-target pairs
                seq = indexed_sentence[:self.seq_length]
                target = indexed_sentence[1:self.seq_length + 1]

                data.append((seq, target))
        return data

    def __len__(self):
        return len(self.data)

    def __getitem__(self, idx):
        seq, target = self.data[idx]
        return torch.tensor(seq), torch.tensor(target)
```

Class: `LanguageModelDataset`

- **Purpose**: Prepares and manages a dataset of text sequences for training a language model.

Constructor: `__init__`

- **Purpose**: Initializes the dataset with sentences, vocabulary mappings, and sequence length. Calls `prepare_data` to process the sentences.

Method: `prepare_data`

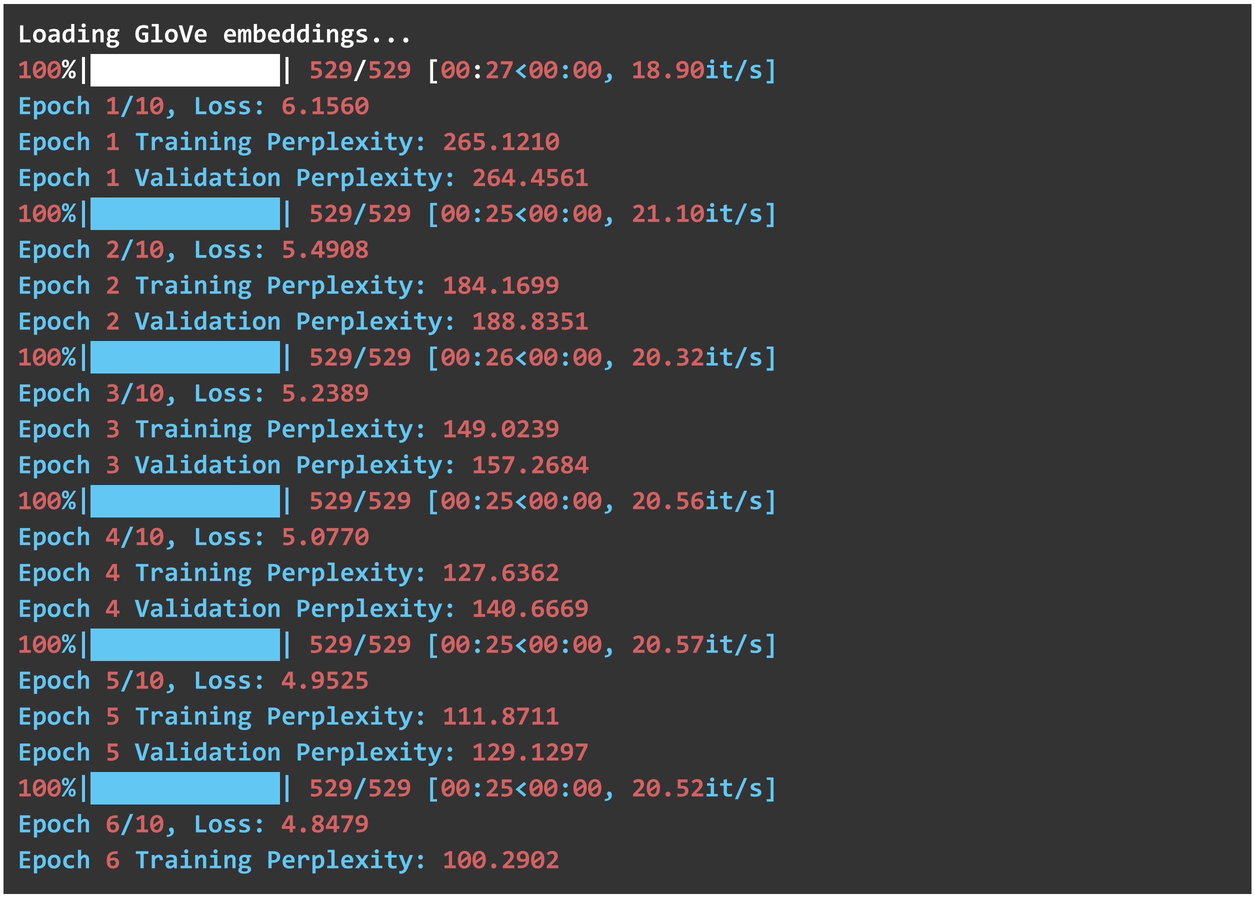
- **Purpose**: Converts sentences into sequences of indices. Pads or truncates sequences to a fixed length. Creates input-target pairs for model training.

Method: `__len__`

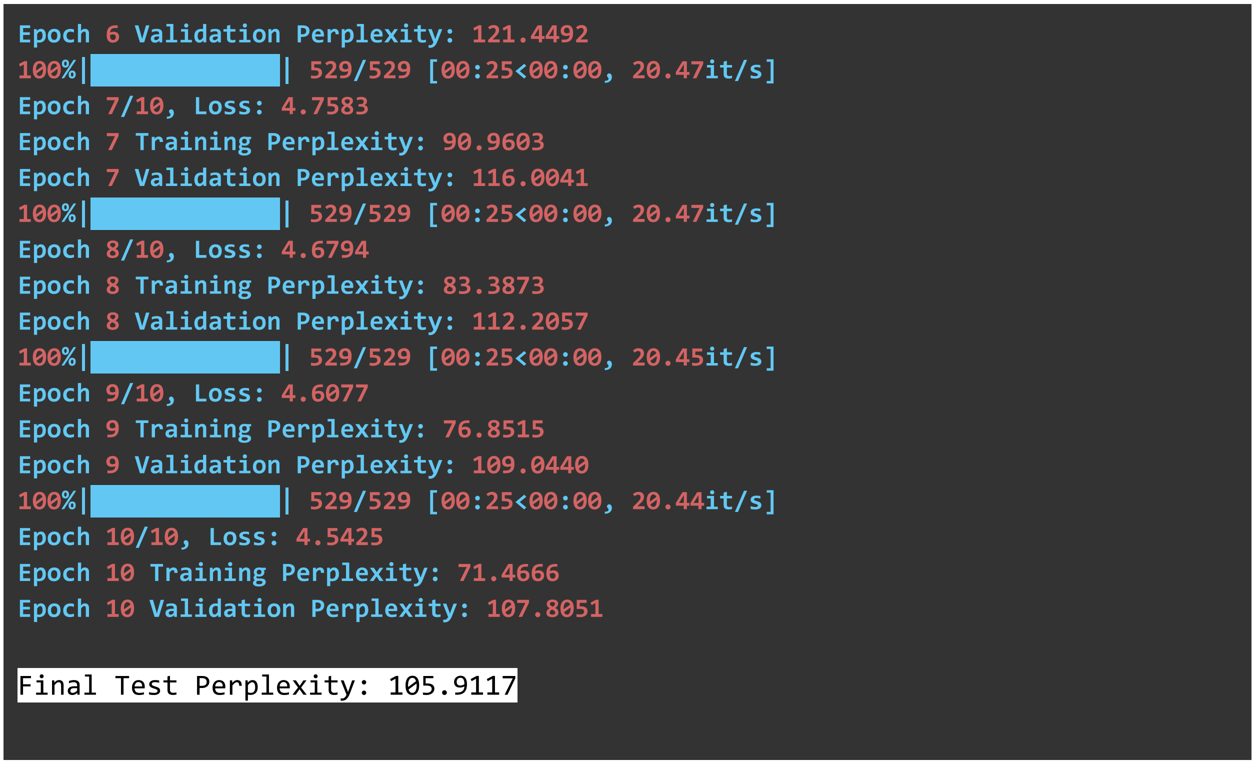
- **Purpose**: Returns the number of data pairs in the dataset.

Method: `__getitem__`

- **Purpose**: Retrieves the input and target tensors for a given index.



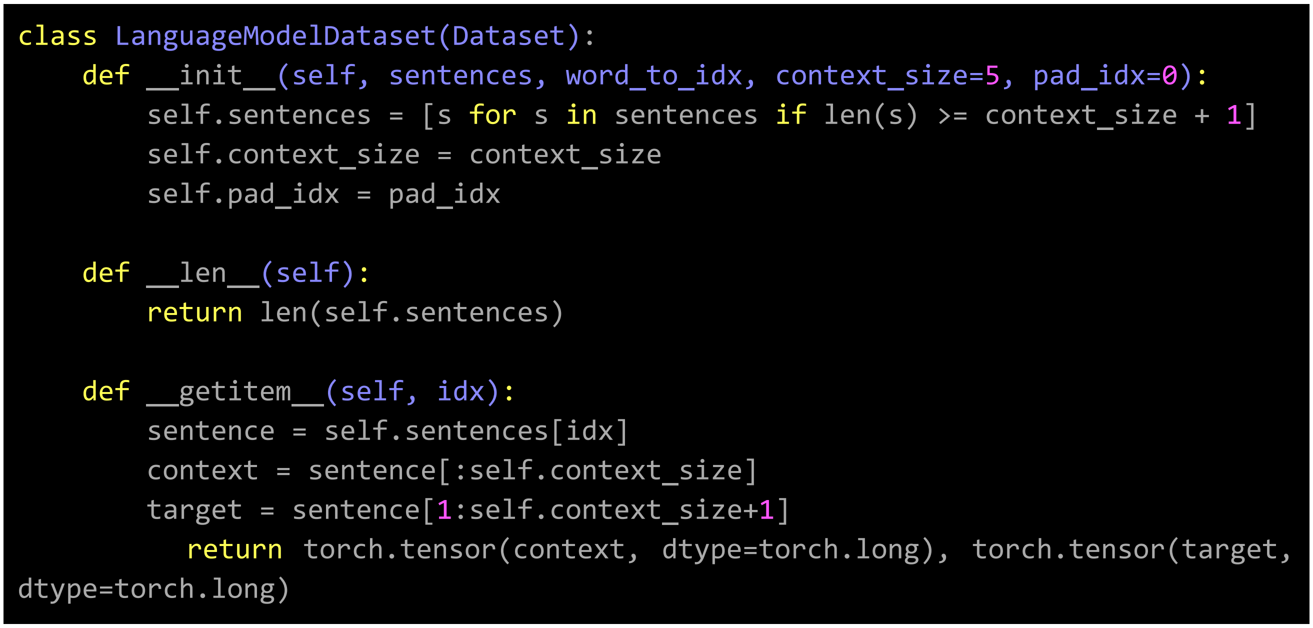
```
Loading GloVe embeddings...
100%|██████████| 529/529 [00:27<00:00, 18.90it/s]
Epoch 1/10, Loss: 6.1560
Epoch 1 Training Perplexity: 265.1210
Epoch 1 Validation Perplexity: 264.4561
100%|██████████| 529/529 [00:25<00:00, 21.10it/s]
Epoch 2/10, Loss: 5.4908
Epoch 2 Training Perplexity: 184.1699
Epoch 2 Validation Perplexity: 188.8351
100%|██████████| 529/529 [00:26<00:00, 20.32it/s]
Epoch 3/10, Loss: 5.2389
Epoch 3 Training Perplexity: 149.0239
Epoch 3 Validation Perplexity: 157.2684
100%|██████████| 529/529 [00:25<00:00, 20.56it/s]
Epoch 4/10, Loss: 5.0770
Epoch 4 Training Perplexity: 127.6362
Epoch 4 Validation Perplexity: 140.6669
100%|██████████| 529/529 [00:25<00:00, 20.57it/s]
Epoch 5/10, Loss: 4.9525
Epoch 5 Training Perplexity: 111.8711
Epoch 5 Validation Perplexity: 129.1297
100%|██████████| 529/529 [00:25<00:00, 20.52it/s]
Epoch 6/10, Loss: 4.8479
Epoch 6 Training Perplexity: 100.2902
```



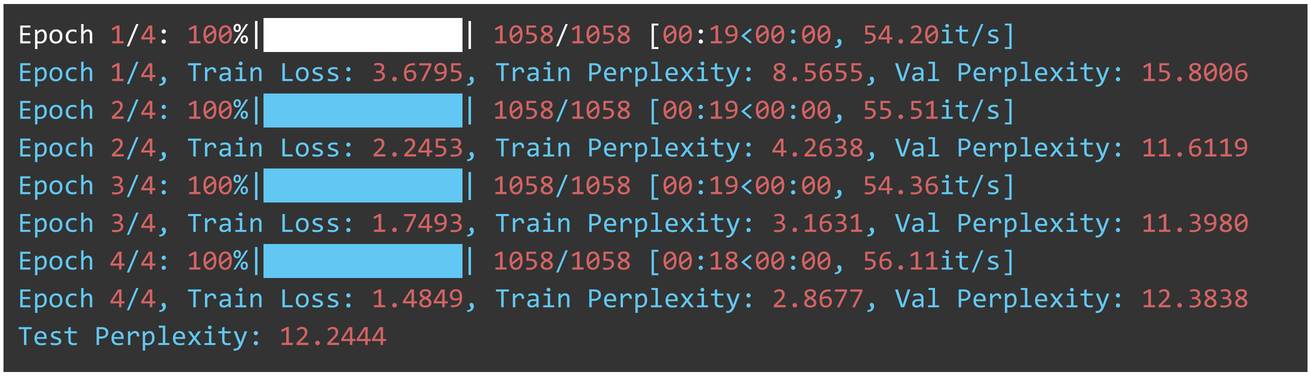
```
Epoch 6 Validation Perplexity: 121.4492
100%|██████████| 529/529 [00:25<00:00, 20.47it/s]
Epoch 7/10, Loss: 4.7583
Epoch 7 Training Perplexity: 90.9603
Epoch 7 Validation Perplexity: 116.0041
100%|██████████| 529/529 [00:25<00:00, 20.47it/s]
Epoch 8/10, Loss: 4.6794
Epoch 8 Training Perplexity: 83.3873
Epoch 8 Validation Perplexity: 112.2057
100%|██████████| 529/529 [00:25<00:00, 20.45it/s]
Epoch 9/10, Loss: 4.6077
Epoch 9 Training Perplexity: 76.8515
Epoch 9 Validation Perplexity: 109.0440
100%|██████████| 529/529 [00:25<00:00, 20.44it/s]
Epoch 10/10, Loss: 4.5425
Epoch 10 Training Perplexity: 71.4666
Epoch 10 Validation Perplexity: 107.8051

Final Test Perplexity: 105.9117
```

3 Transformer Decoder based Language Model:

For the 1st version:

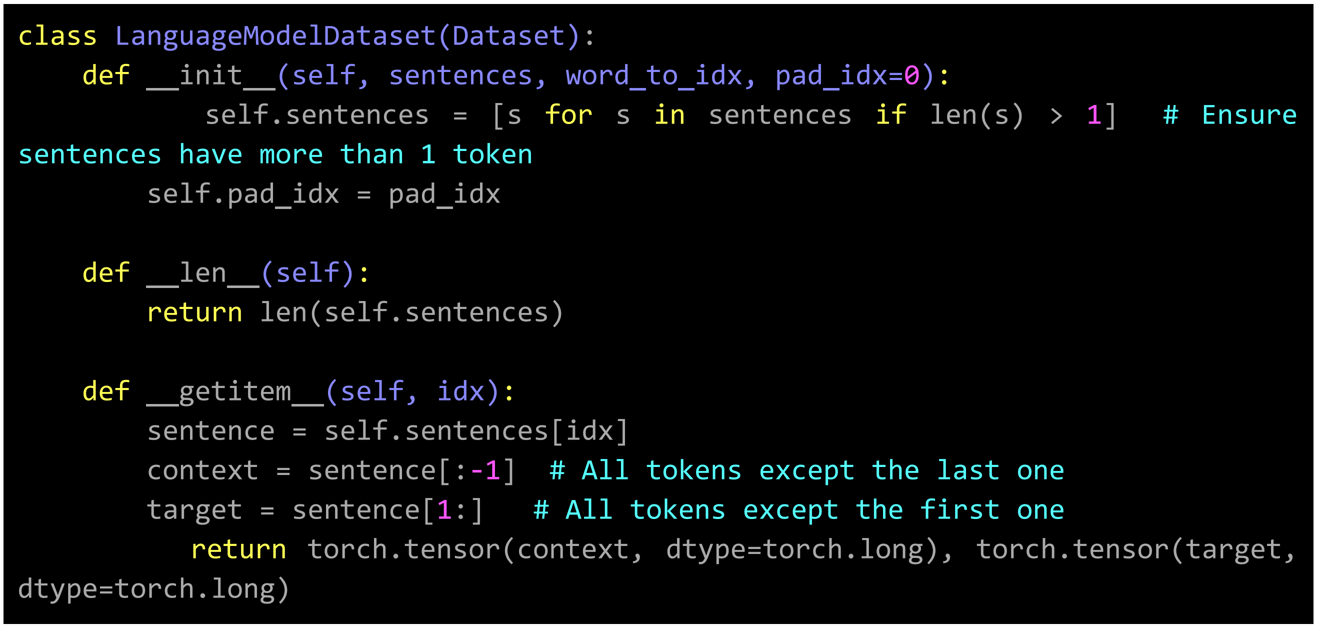


```
class LanguageModelDataset(Dataset):
    def __init__(self, sentences, word_to_idx, context_size=5, pad_idx=0):
        self.sentences = [s for s in sentences if len(s) >= context_size + 1]
        self.context_size = context_size
        self.pad_idx = pad_idx

    def __len__(self):
        return len(self.sentences)

    def __getitem__(self, idx):
        sentence = self.sentences[idx]
        context = sentence[:self.context_size]
        target = sentence[1:self.context_size+1]
          return torch.tensor(context, dtype=torch.long), torch.tensor(target,
dtype=torch.long)
```

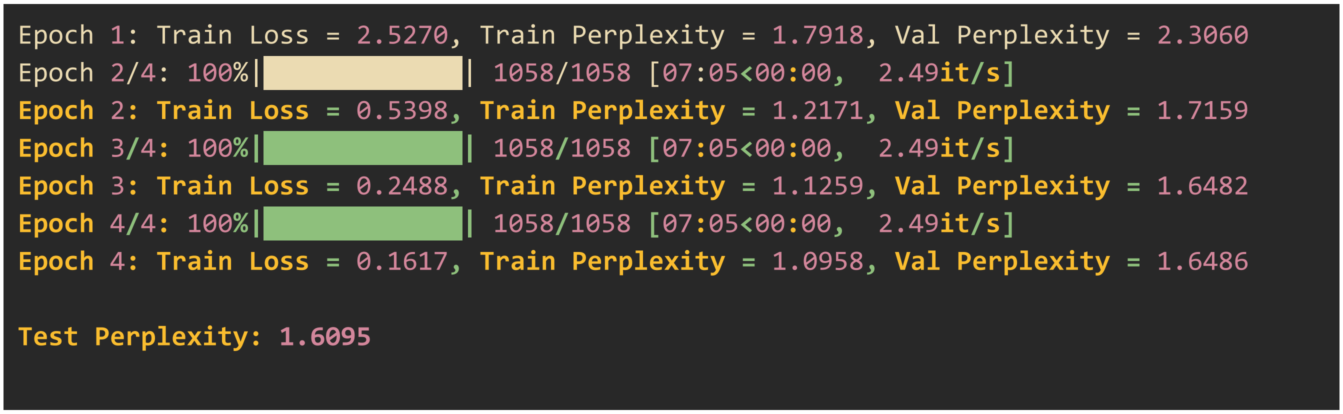


```
Epoch 1/4: 100%|██████████| 1058/1058 [00:19<00:00, 54.20it/s]
Epoch 1/4, Train Loss: 3.6795, Train Perplexity: 8.5655, Val Perplexity: 15.8006
Epoch 2/4: 100%|██████████| 1058/1058 [00:19<00:00, 55.51it/s]
Epoch 2/4, Train Loss: 2.2453, Train Perplexity: 4.2638, Val Perplexity: 11.6119
Epoch 3/4: 100%|██████████| 1058/1058 [00:19<00:00, 54.36it/s]
Epoch 3/4, Train Loss: 1.7493, Train Perplexity: 3.1631, Val Perplexity: 11.3980
Epoch 4/4: 100%|██████████| 1058/1058 [00:18<00:00, 56.11it/s]
Epoch 4/4, Train Loss: 1.4849, Train Perplexity: 2.8677, Val Perplexity: 12.3838
Test Perplexity: 12.2444
```

For the 2nd version:

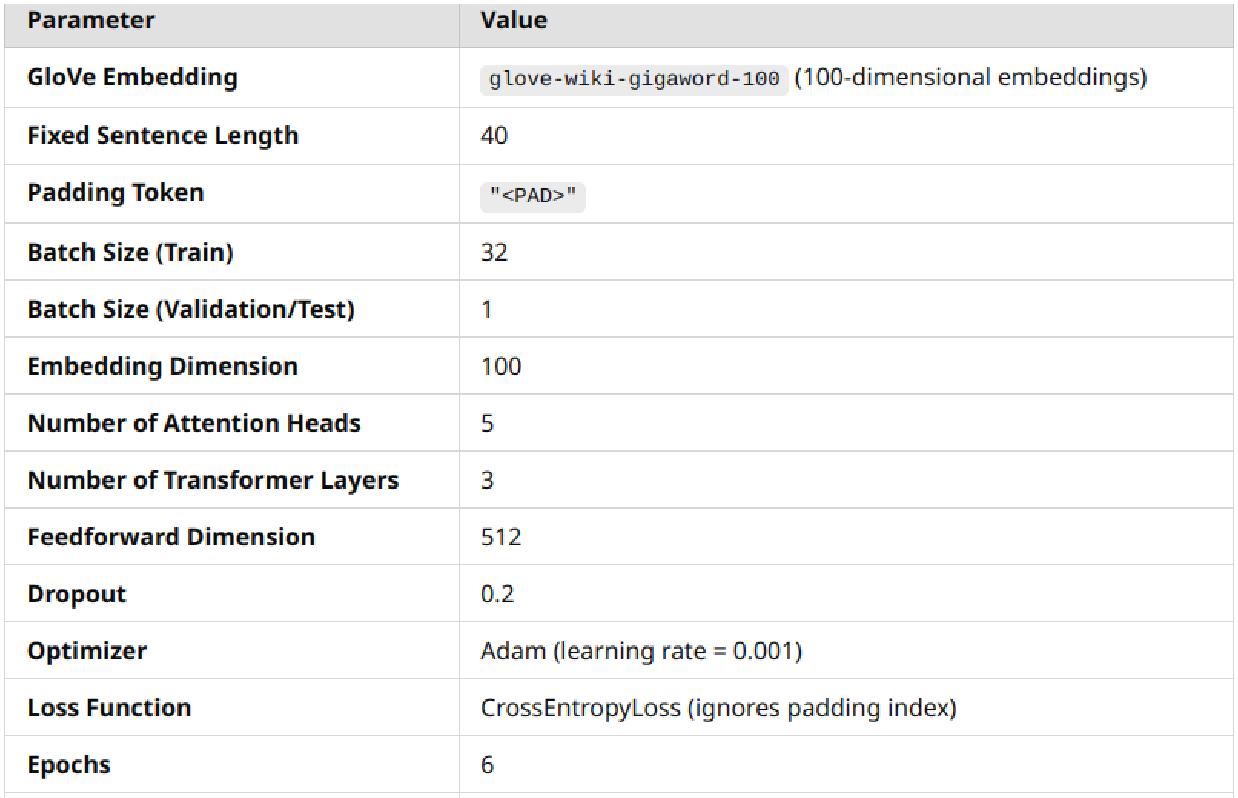


```
class LanguageModelDataset(Dataset):
    def __init__(self, sentences, word_to_idx, pad_idx=0):
           self.sentences = [s for s in sentences if len(s) > 1]   # Ensure
sentences have more than 1 token
        self.pad_idx = pad_idx

    def __len__(self):
        return len(self.sentences)

    def __getitem__(self, idx):
        sentence = self.sentences[idx]
        context = sentence[:-1]  # All tokens except the last one
        target = sentence[1:]   # All tokens except the first one
           return torch.tensor(context, dtype=torch.long), torch.tensor(target,
dtype=torch.long)
```



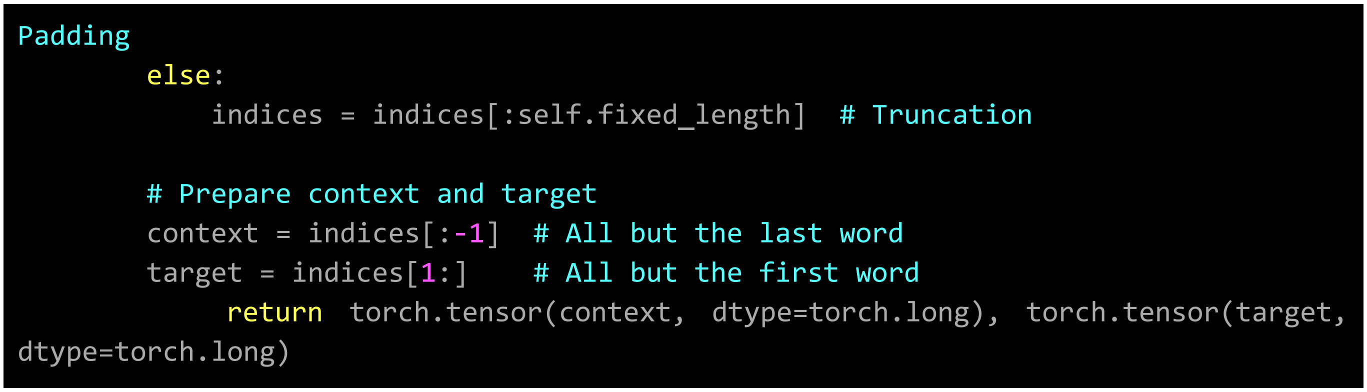
```
Epoch 1: Train Loss = 2.5270, Train Perplexity = 1.7918, Val Perplexity = 2.3060
Epoch 2/4: 100%|██████████| 1058/1058 [07:05<00:00,  2.49it/s]
Epoch 2: Train Loss = 0.5398, Train Perplexity = 1.2171, Val Perplexity = 1.7159
Epoch 3/4: 100%|██████████| 1058/1058 [07:05<00:00,  2.49it/s]
Epoch 3: Train Loss = 0.2488, Train Perplexity = 1.1259, Val Perplexity = 1.6482
Epoch 4/4: 100%|██████████| 1058/1058 [07:05<00:00,  2.49it/s]
Epoch 4: Train Loss = 0.1617, Train Perplexity = 1.0958, Val Perplexity = 1.6486

Test Perplexity: 1.6095
```

For the 3rd version:

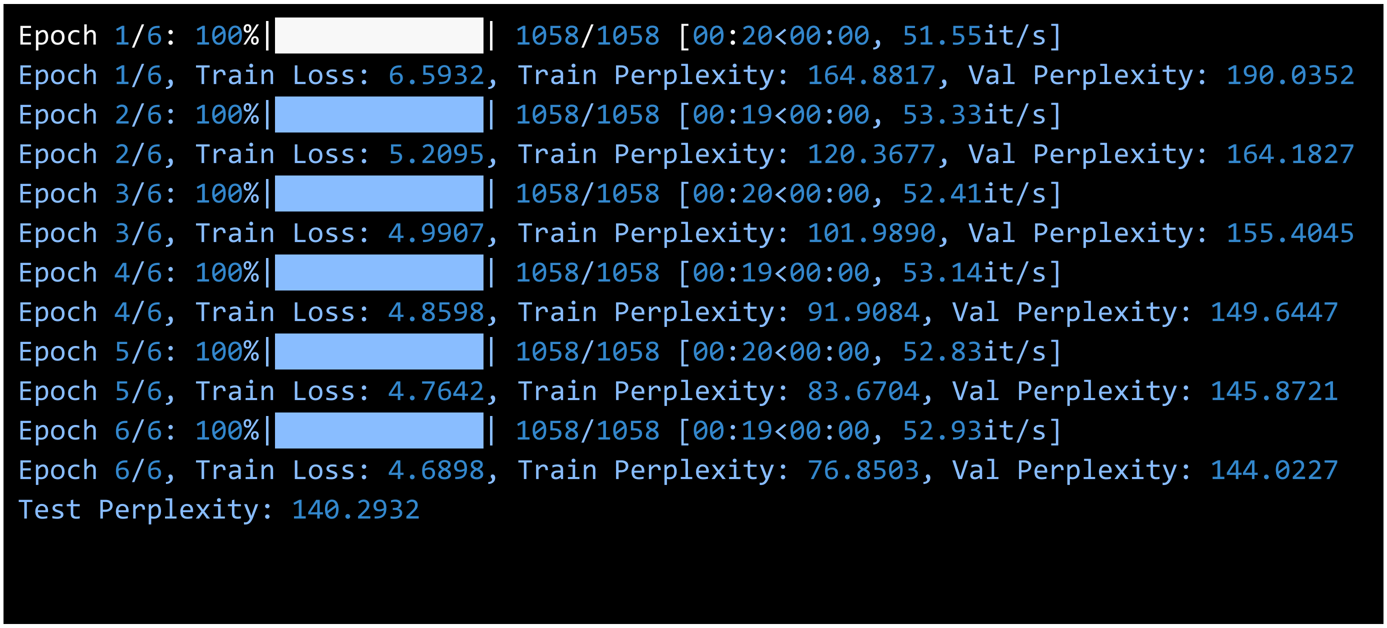


Parameter	Value
GloVe Embedding	`glove-wiki-gigaword-100` (100-dimensional embeddings)
Fixed Sentence Length	40
Padding Token	`"<PAD>"`
Batch Size (Train)	32
Batch Size (Validation/Test)	1
Embedding Dimension	100
Number of Attention Heads	5
Number of Transformer Layers	3
Feedforward Dimension	512
Dropout	0.2
Optimizer	Adam (learning rate = 0.001)
Loss Function	CrossEntropyLoss (ignores padding index)
Epochs	6

```
class LanguageModelDataset(Dataset):
    def __init__(self, sentences, word_to_idx, fixed_length=40, pad_idx=0):
         self.sentences = [s for s in sentences if len(s) > 0]  # Filter out empty sentences
        self.word_to_idx = word_to_idx
        self.fixed_length = fixed_length
        self.pad_idx = pad_idx

    def __len__(self):
        return len(self.sentences)

    def __getitem__(self, idx):
        sentence = self.sentences[idx]
        # Convert words to indices
         indices = [self.word_to_idx.get(word, self.word_to_idx["<UNK>"]) for word in sentence]

        # Pad or truncate to fixed length
        if len(indices) < self.fixed_length:
                indices += [self.pad_idx] * (self.fixed_length - len(indices))   #
```



```
Padding
        else:
            indices = indices[:self.fixed_length]  # Truncation

        # Prepare context and target
        context = indices[:-1]  # All but the last word
        target = indices[1:]    # All but the first word
            return torch.tensor(context, dtype=torch.long), torch.tensor(target,
dtype=torch.long)
```



```
Epoch 1/6: 100%|██████████| 1058/1058 [00:20<00:00, 51.55it/s]
Epoch 1/6, Train Loss: 6.5932, Train Perplexity: 164.8817, Val Perplexity: 190.0352
Epoch 2/6: 100%|██████████| 1058/1058 [00:19<00:00, 53.33it/s]
Epoch 2/6, Train Loss: 5.2095, Train Perplexity: 120.3677, Val Perplexity: 164.1827
Epoch 3/6: 100%|██████████| 1058/1058 [00:20<00:00, 52.41it/s]
Epoch 3/6, Train Loss: 4.9907, Train Perplexity: 101.9890, Val Perplexity: 155.4045
Epoch 4/6: 100%|██████████| 1058/1058 [00:19<00:00, 53.14it/s]
Epoch 4/6, Train Loss: 4.8598, Train Perplexity: 91.9084, Val Perplexity: 149.6447
Epoch 5/6: 100%|██████████| 1058/1058 [00:20<00:00, 52.83it/s]
Epoch 5/6, Train Loss: 4.7642, Train Perplexity: 83.6704, Val Perplexity: 145.8721
Epoch 6/6: 100%|██████████| 1058/1058 [00:19<00:00, 52.93it/s]
Epoch 6/6, Train Loss: 4.6898, Train Perplexity: 76.8503, Val Perplexity: 144.0227
Test Perplexity: 140.2932
```

Analysis

Model	Context/Sequence Size	Test Perplexity
Neural Network (NN)	5	266.9687
LSTM	40	105.9117
Transformer Decoder v-1	5	12.244
Transformer Decoder v-2	Full sequence	1.6095
Transformer Decoder v-3	40	140.2932

Analysis:

1. **Neural Network (NN)** with a small context size of 5 yields the **highest perplexity (266.9687)**, indicating it struggles to capture long-range dependencies and perform well in language modeling tasks, especially with limited context.
2. **LSTM** shows a **significant improvement (105.9117 perplexity)** when using a sequence length of 40, reflecting its ability to capture longer-term dependencies better than the NN. LSTMs are known for handling sequential data well by maintaining a memory of previous words.
3. **Transformer Decoder v-1**, using a small context size of 5, performs **far better than the NN and LSTM** with a perplexity of **12.244**. This suggests that even with limited context, transformers outperform traditional architectures in handling dependencies.
4. **Transformer Decoder v-2**, which uses the full sequence as context, achieves a perplexity of **1.6095**—the best result among all models. This highlights the transformer's ability to leverage the entire sequence effectively for predicting the next token, making it highly efficient.
5. **Transformer Decoder v-3**, with a sequence length of 40, shows a **higher perplexity (140.2932)** compared to the v-1 and v-2 versions. This could be due to limitations in capturing sequence information optimally with the specific setup and paarmeters.