1. Introduction:

Natural Language Processing (NLP) tasks often require efficient techniques for representing and analyzing textual data. Singular Value Decomposition (SVD) and Word2Vec are two widely used approaches for this purpose. This report aims to provide a comparative analysis of these techniques, exploring why one might perform better than the other in various scenarios.

2. Overview of Techniques:

a. Singular Value Decomposition (SVD):

- SVD is a linear algebra technique used for dimensionality reduction and feature extraction.
- In the context of NLP, SVD can be applied to create dense vector representations of words or documents.
- It operates by decomposing a matrix into three constituent matrices, retaining the most important information in a lower-dimensional space.

b. Word2Vec:

- Word2Vec is a shallow neural network-based technique for generating word embeddings.
- It captures the semantic relationships between words by representing them as dense vectors in a continuous vector space.
- Word2Vec models, such as Continuous Bag of Words (CBOW) and Skip-gram, are trained on large corpora to learn word embeddings.

3. Performance Comparison:

a. Contextual Information:

- Word2Vec typically outperforms SVD in capturing contextual information and semantic relationships between words.
- SVD relies on global statistics of the corpus, which may not capture fine-grained semantic nuances present in the data.
- Word2Vec, on the other hand, learns from local word co-occurrence patterns, allowing it to capture context-specific meanings more effectively.

b. Dimensionality and Sparsity:

- SVD is advantageous in handling high-dimensional, sparse data matrices commonly encountered in NLP tasks.
- It reduces dimensionality while preserving the most relevant information, making it suitable for tasks with large feature spaces.
- Word2Vec, although effective, may struggle with extremely high-dimensional data or datasets with significant sparsity, as it relies on dense vector representations.

c. Training Efficiency:

- Word2Vec training can be computationally intensive, especially when dealing with large corpora.
- SVD, once the initial decomposition is performed, can be more computationally efficient for subsequent operations.

- However, the training process of Word2Vec can be parallelized and optimized using techniques like negative sampling or hierarchical softmax.

4. Application Specific Considerations:

a. SVD:

- SVD is well-suited for tasks requiring dimensionality reduction, such as document clustering or latent semantic analysis.
- It may be preferred in scenarios where interpretability of dimensions is crucial, as the resulting vectors are orthogonal.

b. Word2Vec:

- Word2Vec excels in tasks requiring semantic similarity, such as word analogy tasks or recommendation systems.
- Its ability to capture contextual information makes it valuable in applications like sentiment analysis or machine translation.

5. Conclusion:

- The choice between SVD and Word2Vec depends on the specific requirements and characteristics of the NLP task at hand.
- SVD is advantageous for dimensionality reduction and interpretability, while Word2Vec is more effective in capturing semantic relationships and contextual information.
- Hybrid approaches combining the strengths of both techniques may provide further improvements in NLP tasks.

6. Future Directions:

- Further research could explore hybrid models that integrate SVD and Word2Vec to leverage their complementary strengths.
- Investigating advanced techniques such as contextualized word embeddings (e.g., BERT) could lead to even better performance in NLP tasks.

Possible shortcomings of both Singular Value Decomposition (SVD) and Word2Vec techniques:

1. Shortcomings of SVD:

a. Computational Complexity: SVD can be computationally expensive, especially for large matrices. The time and memory requirements increase significantly with the size of the input data.

b. Sensitivity to Noise: SVD is sensitive to noise present in the data. Noisy or irrelevant features may affect the quality of the decomposition, leading to suboptimal representations.

c. Lack of Contextual Information: SVD treats each word or document as an independent entity and does not consider contextual information. This may limit its effectiveness in capturing subtle semantic relationships present in the data.

d. Interpretability of Dimensions: While SVD provides a reduced-dimensional representation of the data, interpreting the meaning of each dimension can be challenging, especially in high-dimensional spaces.

2. Shortcomings of Word2Vec:

a. Limited Vocabulary Coverage: Word2Vec relies on the vocabulary present in the training corpus. Rare or out-of-vocabulary words may not have meaningful embeddings, impacting the performance of downstream tasks.

b. Lack of Morphological Information: Word2Vec treats each word as a discrete entity and does not explicitly model morphological variations. This can lead to ambiguity in cases where words have multiple meanings or forms.

c. Context Window Size Sensitivity: The performance of Word2Vec models can be sensitive to the choice of context window size during training. A small window size may capture local context but overlook broader semantic relationships, while a large window size may dilute the contextual information.

d. Inability to Handle Polysemy and Homonymy: Word2Vec may struggle to distinguish between words with multiple meanings (polysemy) or different words with the same spelling (homonymy). This can result in ambiguous embeddings, affecting the quality of semantic representations.

SVD

Window Size = 1

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:38<02:33, 38.30s/it]
Epoch 1/5, Training Loss: 0.852764750863115, Validation Accuracy:
0.767875
2  train
eval

40%|████      | 2/5 [01:16<01:54, 38.29s/it]
Epoch 2/5, Training Loss: 0.6115492423921823, Validation Accuracy:
0.7923333333333333
3  train
eval

60%|██████    | 3/5 [01:54<01:16, 38.34s/it]
Epoch 3/5, Training Loss: 0.581640526180466, Validation Accuracy:
0.7895833333333333
4  train
eval

80%|████████  | 4/5 [02:33<00:38, 38.37s/it]
Epoch 4/5, Training Loss: 0.5518011406908433, Validation Accuracy:
0.8016666666666666
5  train
eval

100%|██████████| 5/5 [03:11<00:00, 38.38s/it]

Epoch 5/5, Training Loss: 0.5776388226846854, Validation Accuracy:
0.7797083333333333
SL

val
100%|██████████| 750/750 [00:04<00:00, 163.87it/s]
```

Accuracy on the val set: 0.8016666666666666 for window_size = 1

Classification Report:

	precision	**recall**	**f1-score**	**support**

```
           0       0.79      0.83      0.80      5956
           1       0.87      0.91      0.89      6058
           2       0.75      0.76      0.75      5911
           3       0.79      0.71      0.75      6075

    accuracy                           0.80     24000
   macro avg       0.80      0.80      0.80     24000
weighted avg       0.80      0.80      0.80     24000

Confusion Matrix:
[[4917  367  433  239]
 [ 279 5540  110  129]
 [ 509  169 4483  750]
 [ 558  257  960 4300]]
Micro Recall: 0.8016666666666666
Macro Recall: 0.801570684212283
Micro F1 Score: 0.8016666666666666
Macro F1 Score: 0.8002316280118449

test
100%|██████████| 238/238 [00:01<00:00, 166.06it/s]

Accuracy on the test set: 0.8057894736842105 for window_size = 1
Classification Report:
              precision    recall  f1-score   support

           0       0.79      0.83      0.81      1900
           1       0.87      0.92      0.90      1900
           2       0.76      0.75      0.76      1900
           3       0.80      0.72      0.76      1900

    accuracy                           0.81      7600
   macro avg       0.80      0.81      0.80      7600
weighted avg       0.80      0.81      0.80      7600

Confusion Matrix:
[[1581  117  133   69]
 [  91 1746   31   32]
 [ 161   62 1428  249]
 [ 169   74  288 1369]]
Micro Recall: 0.8057894736842105
Macro Recall: 0.8057894736842105
Micro F1 Score: 0.8057894736842105
Macro F1 Score: 0.8045215166898371
```

Window Size = 2

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:38<02:34, 38.70s/it]
Epoch 1/5, Training Loss: 0.6483001074592273, Validation Accuracy:
0.8152083333333333
2  train
eval

40%|████      | 2/5 [01:17<01:55, 38.60s/it]
Epoch 2/5, Training Loss: 0.4964836343800028, Validation Accuracy:
0.8333333333333334
3  train
eval

60%|██████    | 3/5 [01:55<01:17, 38.62s/it]
Epoch 3/5, Training Loss: 0.47749319673081236, Validation Accuracy:
0.812
4  train
eval

80%|████████  | 4/5 [02:34<00:38, 38.61s/it]
Epoch 4/5, Training Loss: 0.4767883803471923, Validation Accuracy:
0.8339166666666666
5  train
eval

100%|██████████| 5/5 [03:12<00:00, 38.58s/it]

Epoch 5/5, Training Loss: 0.4636848146195213, Validation Accuracy:
0.8151666666666667
SL

val
100%|██████████| 750/750 [00:04<00:00, 165.84it/s]
```

Accuracy on the val set: 0.8339166666666666 for window_size = 2

Classification Report:

	precision	**recall**	**f1-score**	**support**
0	**0.87**	**0.81**	**0.84**	**5956**

```
           1       0.89      0.93      0.91      6058
           2       0.78      0.80      0.79      5911
           3       0.80      0.79      0.79      6075

    accuracy                           0.83     24000
   macro avg       0.83      0.83      0.83     24000
weighted avg       0.83      0.83      0.83     24000

Confusion Matrix:
[[4849  360  429  318]
 [ 197 5635  110  116]
 [ 283  136 4756  736]
 [ 269  211  821 4774]]
Micro Recall: 0.8339166666666666
Macro Recall: 0.8336892978987819
Micro F1 Score: 0.8339166666666666
Macro F1 Score: 0.8333824955241906
```

```
test
100%|██████████| 238/238 [00:01<00:00, 167.45it/s]

Accuracy on the test set: 0.8338157894736842 for window_size = 2
Classification Report:
              precision    recall  f1-score   support

           0       0.87      0.81      0.84      1900
           1       0.90      0.93      0.91      1900
           2       0.78      0.79      0.79      1900
           3       0.79      0.81      0.80      1900

    accuracy                           0.83      7600
   macro avg       0.83      0.83      0.83      7600
weighted avg       0.83      0.83      0.83      7600

Confusion Matrix:
[[1539  102  150  109]
 [  66 1762   36   36]
 [  87   47 1504  262]
 [  81   53  234 1532]]
Micro Recall: 0.8338157894736842
Macro Recall: 0.8338157894736843
Micro F1 Score: 0.8338157894736842
Macro F1 Score: 0.8336876876271059
```

Window Size = 3

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:39<02:37, 39.40s/it]
Epoch 1/5, Training Loss: 0.6074001341561477, Validation Accuracy:
0.8136666666666666
2  train
eval

40%|████      | 2/5 [01:18<01:58, 39.46s/it]
Epoch 2/5, Training Loss: 0.4791638012950619, Validation Accuracy:
0.8351666666666666
3  train
eval

60%|██████    | 3/5 [01:58<01:18, 39.35s/it]
Epoch 3/5, Training Loss: 0.4508361997331182, Validation Accuracy:
0.8389166666666666
4  train
eval

80%|████████  | 4/5 [02:37<00:39, 39.37s/it]
Epoch 4/5, Training Loss: 0.4495208443328738, Validation Accuracy:
0.8457916666666667
5  train
eval

100%|██████████| 5/5 [03:17<00:00, 39.43s/it]

Epoch 5/5, Training Loss: 0.4595630116586884, Validation Accuracy:
0.8448333333333333
SL

val
100%|██████████| 750/750 [00:04<00:00, 157.96it/s]
```

Accuracy on the val set: 0.8457916666666667 for window_size = 3

Classification Report:

	precision	**recall**	**f1-score**	**support**
0	**0.88**	**0.82**	**0.85**	**5956**

```
           1       0.89      0.95      0.92      6058
           2       0.83      0.76      0.80      5911
           3       0.79      0.84      0.81      6075

    accuracy                           0.85     24000
   macro avg       0.85      0.85      0.84     24000
weighted avg       0.85      0.85      0.84     24000

Confusion Matrix:
[[4898  348  379  331]
 [  96 5785   30  147]
 [ 307  174 4517  913]
 [ 258  206  512 5099]]
Micro Recall: 0.8457916666666667
Macro Recall: 0.8452024220494637
Micro F1 Score: 0.8457916666666667
Macro F1 Score: 0.8446813976629435


test
100%|██████████| 238/238 [00:01<00:00, 160.52it/s]

Accuracy on the test set: 0.8413157894736842 for window_size = 3
Classification Report:
              precision    recall  f1-score   support

           0       0.88      0.81      0.85      1900
           1       0.89      0.95      0.92      1900
           2       0.83      0.76      0.79      1900
           3       0.77      0.85      0.81      1900

    accuracy                           0.84      7600
   macro avg       0.84      0.84      0.84      7600
weighted avg       0.84      0.84      0.84      7600

Confusion Matrix:
[[1543  106  135  116]
 [  45 1803   17   35]
 [  88   57 1436  319]
 [  76   64  148 1612]]
Micro Recall: 0.8413157894736842
Macro Recall: 0.8413157894736842
Micro F1 Score: 0.8413157894736842
Macro F1 Score: 0.84052401610993
```

Window Size = 4

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:38<02:34, 38.53s/it]
Epoch 1/5, Training Loss: 0.5729669326146444, Validation Accuracy:
0.839875
2  train
eval

40%|████      | 2/5 [01:16<01:55, 38.45s/it]
Epoch 2/5, Training Loss: 0.4475169484317303, Validation Accuracy:
0.8403333333333334
3  train
eval

60%|██████    | 3/5 [01:55<01:17, 38.58s/it]
Epoch 3/5, Training Loss: 0.42645969009151063, Validation Accuracy:
0.8550416666666667
4  train
eval

80%|████████  | 4/5 [02:34<00:38, 38.55s/it]
Epoch 4/5, Training Loss: 0.41940271618713937, Validation Accuracy:
0.8483333333333334
5  train
eval

100%|██████████| 5/5 [03:12<00:00, 38.52s/it]

Epoch 5/5, Training Loss: 0.4163943541025122, Validation Accuracy:
0.8420416666666667
SL

val
100%|██████████| 750/750 [00:04<00:00, 165.55it/s]
```

Accuracy on the val set: 0.8550416666666667 for window_size = 4

Classification Report:

	precision	**recall**	**f1-score**	**support**
0	**0.87**	**0.84**	**0.86**	**5956**

```
           1       0.90      0.94      0.92      6058
           2       0.83      0.79      0.81      5911
           3       0.81      0.84      0.83      6075

    accuracy                           0.86     24000
   macro avg       0.85      0.85      0.85     24000
weighted avg       0.85      0.86      0.85     24000

Confusion Matrix:
[[5010  301  367  278]
 [ 149 5707   98  104]
 [ 298  144 4686  783]
 [ 291  155  511 5118]]
Micro Recall: 0.8550416666666667
Macro Recall: 0.8546142633853169
Micro F1 Score: 0.8550416666666667
Macro F1 Score: 0.8543280624798004



test
100%|██████████| 238/238 [00:01<00:00, 167.18it/s]

Accuracy on the test set: 0.8544736842105263 for window_size = 4
Classification Report:
              precision    recall  f1-score   support

           0       0.87      0.85      0.86      1900
           1       0.91      0.94      0.93      1900
           2       0.82      0.78      0.80      1900
           3       0.81      0.85      0.83      1900

    accuracy                           0.85      7600
   macro avg       0.85      0.85      0.85      7600
weighted avg       0.85      0.85      0.85      7600

Confusion Matrix:
[[1610   92  115   83]
 [  53 1791   37   19]
 [  93   48 1487  272]
 [  86   41  167 1606]]
Micro Recall: 0.8544736842105263
Macro Recall: 0.8544736842105264
Micro F1 Score: 0.8544736842105263
Macro F1 Score: 0.8539808058341799
```

Window Size = 5

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:40<02:40, 40.01s/it]
Epoch 1/5, Training Loss: 0.6355001035407185, Validation Accuracy:
0.838875
2  train
eval

40%|████      | 2/5 [01:19<01:59, 39.79s/it]
Epoch 2/5, Training Loss: 0.44717856097469727, Validation Accuracy:
0.842375
3  train
eval

60%|██████    | 3/5 [01:59<01:19, 39.70s/it]
Epoch 3/5, Training Loss: 0.4283107348630826, Validation Accuracy:
0.8537083333333333
4  train
eval

80%|████████  | 4/5 [02:38<00:39, 39.58s/it]
Epoch 4/5, Training Loss: 0.40998494550089043, Validation Accuracy:
0.8576666666666667
5  train
eval

100%|██████████| 5/5 [03:18<00:00, 39.64s/it]

Epoch 5/5, Training Loss: 0.39662030941744647, Validation Accuracy:
0.8555416666666666
SL

val
100%|██████████| 750/750 [00:04<00:00, 159.96it/s]
```

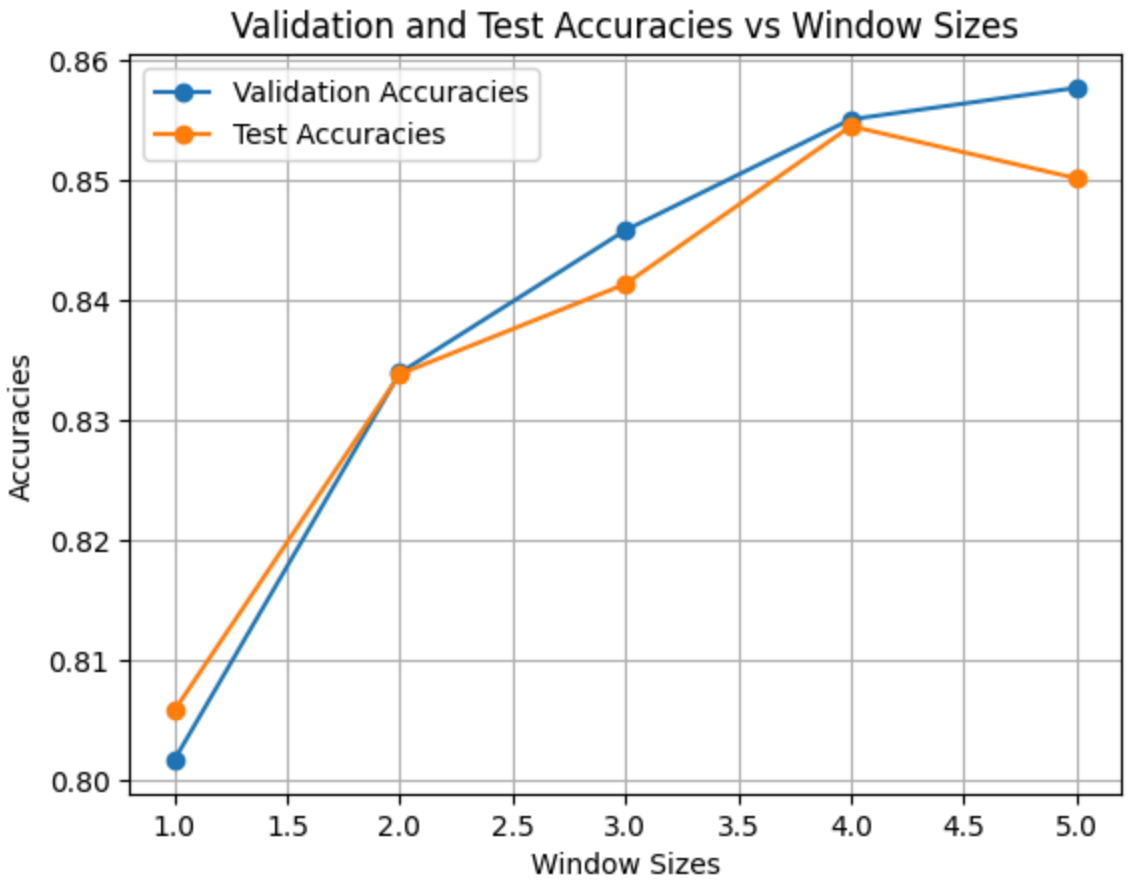
Accuracy on the val set: 0.8576666666666667 for window_size = 5

Classification Report:

	precision	**recall**	**f1-score**	**support**
0	**0.91**	**0.81**	**0.86**	**5956**

```
           1       0.93      0.95      0.94      6058
           2       0.80      0.82      0.81      5911
           3       0.80      0.85      0.82      6075

    accuracy                           0.86     24000
   macro avg       0.86      0.86      0.86     24000
weighted avg       0.86      0.86      0.86     24000

Confusion Matrix:
[[4831  246  471  408]
 [  92 5728   95  143]
 [ 193   84 4853  781]
 [ 182   79  642 5172]]
Micro Recall: 0.8576666666666667
Macro Recall: 0.8572527791117325
Micro F1 Score: 0.8576666666666667
Macro F1 Score: 0.8577471310726379
```

```
test
100%|██████████| 238/238 [00:01<00:00, 156.70it/s]
Accuracy on the test set: 0.8501315789473685 for window_size = 5
Classification Report:
              precision    recall  f1-score   support

           0       0.90      0.81      0.85      1900
           1       0.94      0.93      0.94      1900
           2       0.79      0.80      0.80      1900
           3       0.79      0.86      0.82      1900

    accuracy                           0.85      7600
   macro avg       0.85      0.85      0.85      7600
weighted avg       0.85      0.85      0.85      7600

Confusion Matrix:
[[1533   71  163  133]
 [  40 1776   37   47]
 [  84   26 1527  263]
 [  51   25  199 1625]]
Micro Recall: 0.8501315789473685
Macro Recall: 0.8501315789473683
Micro F1 Score: 0.8501315789473685
Macro F1 Score: 0.8505706111686384
```


Validation and Test Accuracies vs Window Sizes
Validation Accuracies
Test Accuracies
Accuracies
Window Sizes
0.86
0.85
0.84
0.83
0.82
0.81
0.80
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

SGNS

Window Size = 4
TD
1367880

100%|██████████| 1367880/1367880 [11:18<00:00, 2016.27it/s]

9543134
46316 3842

 0%| | 0/5 [00:00<?, ?it/s]
1 trainembed

20%|██ | 1/5 [18:49<1:15:16, 1129.04s/it]
Epoch : 1, mean_loss : 0.714147
2 trainembed

40%|████ | 2/5 [37:33<56:19, 1126.48s/it]
Epoch : 2, mean_loss : 0.656935
3 trainembed

60%|██████ | 3/5 [56:16<37:29, 1124.67s/it]
Epoch : 3, mean_loss : 0.626860
4 trainembed

80%|████████ | 4/5 [1:14:46<18:38, 1118.94s/it]
Epoch : 4, mean_loss : 0.607467
5 trainembed

100%|██████████| 5/5 [1:33:14<00:00, 1118.99s/it]
Epoch : 5, mean_loss : 0.593623

Window Size = 3
TD
1367880

100%|██████████| 1367880/1367880 [08:44<00:00, 2610.44it/s]

7367322
46316 3842

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  trainembed

20%|██        | 1/5 [14:30<58:03, 870.93s/it]
Epoch : 1, mean_loss : 0.693114
2  trainembed

40%|████      | 2/5 [29:07<43:42, 874.12s/it]
Epoch : 2, mean_loss : 0.629358
3  trainembed

60%|██████    | 3/5 [43:38<29:05, 872.78s/it]
Epoch : 3, mean_loss : 0.594379
4  trainembed

80%|████████  | 4/5 [58:26<14:38, 878.83s/it]
Epoch : 4, mean_loss : 0.571439
5  trainembed

100%|██████████| 5/5 [1:13:13<00:00, 878.74s/it]
Epoch : 5, mean_loss : 0.555106
```

Window Size = 2

```
TD
1367880

100%|██████████| 1367880/1367880 [05:49<00:00, 3914.60it/s]

5051534
46316 3842

 0%|          | 0/5 [00:00<?, ?it/s]
1  trainembed

20%|██        | 1/5 [09:56<39:44, 596.24s/it]
Epoch : 1, mean_loss : 0.665493
2  trainembed

40%|████      | 2/5 [19:54<29:52, 597.41s/it]
Epoch : 2, mean_loss : 0.589884
3  trainembed

60%|██████    | 3/5 [29:54<19:56, 598.48s/it]
```

```
Epoch : 3, mean_loss : 0.546985
4  trainembed

80%|████████  | 4/5 [39:51<09:57, 597.97s/it]
Epoch : 4, mean_loss : 0.517973
5  trainembed

100%|██████████| 5/5 [49:51<00:00, 598.33s/it]
Epoch : 5, mean_loss : 0.497168
```

Window Size = 1

```
TD
```

1367880

```
100%|██████████| 1367880/1367880 [03:06<00:00, 7353.45it/s]
```

2595760
46316 3842

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  trainembed

20%|██        | 1/5 [05:08<20:32, 308.21s/it]
Epoch : 1, mean_loss : 0.621972
2  trainembed

40%|████      | 2/5 [10:15<15:23, 307.80s/it]
Epoch : 2, mean_loss : 0.522509
3  trainembed

60%|██████    | 3/5 [15:23<10:15, 307.65s/it]
Epoch : 3, mean_loss : 0.464798
4  trainembed

80%|████████  | 4/5 [20:29<05:07, 307.30s/it]
Epoch : 4, mean_loss : 0.425124
5  trainembed

100%|██████████| 5/5 [25:37<00:00, 307.44s/it]
Epoch : 5, mean_loss : 0.396329
```

Window Size = 1

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:42<02:49, 42.28s/it]
Epoch 1/5, Training Loss: 0.4479149749092758, Validation Accuracy:
0.8942916666666667
2  train
eval

40%|████      | 2/5 [01:23<02:04, 41.59s/it]
Epoch 2/5, Training Loss: 0.2875330467764288, Validation Accuracy:
0.8965833333333333
3  train
eval

60%|██████    | 3/5 [02:04<01:22, 41.41s/it]
Epoch 3/5, Training Loss: 0.2494687021865199, Validation Accuracy:
0.8975833333333333
4  train
eval

80%|████████  | 4/5 [02:46<00:41, 41.43s/it]
Epoch 4/5, Training Loss: 0.22236282429161172, Validation Accuracy:
0.897875
5  train
eval

100%|██████████| 5/5 [03:27<00:00, 41.47s/it]

Epoch 5/5, Training Loss: 0.20057720164582132, Validation Accuracy:
0.89775

SL

val
100%|██████████| 750/750 [00:06<00:00, 119.69it/s]
```

Accuracy on the val set: 0.897875 for window_size = 1

Classification Report:

	precision	**recall**	**f1-score**	**support**

```
              precision    recall  f1-score   support

           0       0.91      0.90      0.90      5956
           1       0.94      0.97      0.96      6058
           2       0.89      0.82      0.86      5911
           3       0.85      0.90      0.87      6075

    accuracy                           0.90     24000
   macro avg       0.90      0.90      0.90     24000
weighted avg       0.90      0.90      0.90     24000

Confusion Matrix:
[[5355  199  182  220]
 [  69 5887   37   65]
 [ 283   90 4856  682]
 [ 184   78  362 5451]]
Micro Recall: 0.897875
Macro Recall: 0.8974173414198202
Micro F1 Score: 0.897875
Macro F1 Score: 0.8972028600341948


test
100%|██████████| 238/238 [00:02<00:00, 118.67it/s]

Accuracy on the test set: 0.8956578947368421 for window_size = 1
Classification Report:
              precision    recall  f1-score   support

           0       0.90      0.90      0.90      1900
           1       0.95      0.97      0.96      1900
           2       0.90      0.82      0.86      1900
           3       0.84      0.89      0.87      1900

    accuracy                           0.90      7600
   macro avg       0.90      0.90      0.90      7600
weighted avg       0.90      0.90      0.90      7600

Confusion Matrix:
[[1710   59   57   74]
 [  25 1838   19   18]
 [ 100   18 1560  222]
 [  69   29  103 1699]]
Micro Recall: 0.8956578947368421
Macro Recall: 0.8956578947368421
Micro F1 Score: 0.8956578947368421
Macro F1 Score: 0.8952787451102531
```

Window Size = 2

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:42<02:48, 42.05s/it]
Epoch 1/5, Training Loss: 0.4539247177032133, Validation Accuracy:
0.8885833333333333
2  train
eval

40%|████      | 2/5 [01:23<02:05, 41.80s/it]
Epoch 2/5, Training Loss: 0.29520885838692384, Validation Accuracy:
0.894875
3  train
eval

60%|██████    | 3/5 [02:05<01:23, 41.65s/it]
Epoch 3/5, Training Loss: 0.25947838578062754, Validation Accuracy:
0.8974166666666666
4  train
eval

80%|████████  | 4/5 [02:46<00:41, 41.61s/it]
Epoch 4/5, Training Loss: 0.23177087166905402, Validation Accuracy:
0.897375
5  train
eval

100%|██████████| 5/5 [03:28<00:00, 41.69s/it]

Epoch 5/5, Training Loss: 0.20931455129012466, Validation Accuracy:
0.8988333333333334

SL

val
100%|██████████| 750/750 [00:06<00:00, 119.49it/s]
```

Accuracy on the val set: 0.8988333333333334 for window_size = 2

Classification Report:

	precision	**recall**	**f1-score**	**support**

```
              precision    recall  f1-score   support

           0       0.90      0.90      0.90      5956
           1       0.94      0.97      0.96      6058
           2       0.87      0.86      0.86      5911
           3       0.88      0.86      0.87      6075

    accuracy                           0.90     24000
   macro avg       0.90      0.90      0.90     24000
weighted avg       0.90      0.90      0.90     24000

Confusion Matrix:
[[5380  185  218  173]
 [  77 5866   61   54]
 [ 250   77 5079  505]
 [ 243   85  500 5247]]
Micro Recall: 0.8988333333333334
Macro Recall: 0.8986365872941593
Micro F1 Score: 0.8988333333333334
Macro F1 Score: 0.8983796630582958


test
100%|██████████| 238/238 [00:02<00:00, 117.01it/s]

Accuracy on the test set: 0.8969473684210526 for window_size = 2
Classification Report:
              precision    recall  f1-score   support

           0       0.90      0.90      0.90      1900
           1       0.95      0.96      0.96      1900
           2       0.86      0.85      0.86      1900
           3       0.86      0.87      0.86      1900

    accuracy                           0.89      7600
   macro avg       0.89      0.89      0.89      7600
weighted avg       0.89      0.89      0.89      7600

Confusion Matrix:
[[1707   63   71   59]
 [  30 1832   25   13]
 [  84   17 1607  192]
 [  73   24  155 1648]]
Micro Recall: 0.8969473684210526
Macro Recall: 0.8969473684210526
Micro F1 Score: 0.8969473684210525
Macro F1 Score: 0.8967209044113161
```

Window Size = 3

DL

```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:41<02:46, 41.56s/it]
Epoch 1/5, Training Loss: 0.4737476342394948, Validation Accuracy:
0.8958333333333334
2  train
eval

40%|████      | 2/5 [01:23<02:04, 41.53s/it]
Epoch 2/5, Training Loss: 0.2840286731297771, Validation Accuracy:
0.8990833333333333
3  train
eval

60%|██████    | 3/5 [02:05<01:23, 41.77s/it]
Epoch 3/5, Training Loss: 0.24783753802378972, Validation Accuracy:
0.9021666666666667
4  train
eval

80%|████████  | 4/5 [02:47<00:42, 42.06s/it]
Epoch 4/5, Training Loss: 0.2195107235542188, Validation Accuracy:
0.902375
5  train
eval

100%|██████████| 5/5 [03:30<00:00, 42.14s/it]

Epoch 5/5, Training Loss: 0.1941241412255913, Validation Accuracy:
0.8975416666666667

SL

val
100%|██████████| 750/750 [00:06<00:00, 116.15it/s]
```

Accuracy on the val set: 0.902375 for window_size = 3

Classification Report:

	precision	**recall**	**f1-score**	**support**

```
           0       0.92      0.89      0.91      5956
           1       0.93      0.98      0.96      6058
           2       0.88      0.86      0.87      5911
           3       0.87      0.88      0.88      6075

    accuracy                           0.90     24000
   macro avg       0.90      0.90      0.90     24000
weighted avg       0.90      0.90      0.90     24000

Confusion Matrix:
[[5325  231  218  182]
 [  44 5939   29   46]
 [ 216   87 5069  539]
 [ 199  109  443 5324]]
Micro Recall: 0.902375
Macro Recall: 0.902086320314277
Micro F1 Score: 0.902375
Macro F1 Score: 0.9017892720758794


test
100%|██████████| 238/238 [00:02<00:00, 115.52it/s]

Accuracy on the test set: 0.9001315789473684 for window_size = 3
Classification Report:
              precision    recall  f1-score   support

           0       0.92      0.90      0.91      1900
           1       0.94      0.97      0.95      1900
           2       0.88      0.85      0.87      1900
           3       0.86      0.88      0.87      1900

    accuracy                           0.90      7600
   macro avg       0.90      0.90      0.90      7600
weighted avg       0.90      0.90      0.90      7600

Confusion Matrix:
[[1701   73   65   61]
 [  24 1848   12   16]
 [  64   23 1619  194]
 [  55   27  145 1673]]
Micro Recall: 0.9001315789473684
Macro Recall: 0.9001315789473684
Micro F1 Score: 0.9001315789473684
Macro F1 Score: 0.899859328081438
```

Window Size = 4

DL

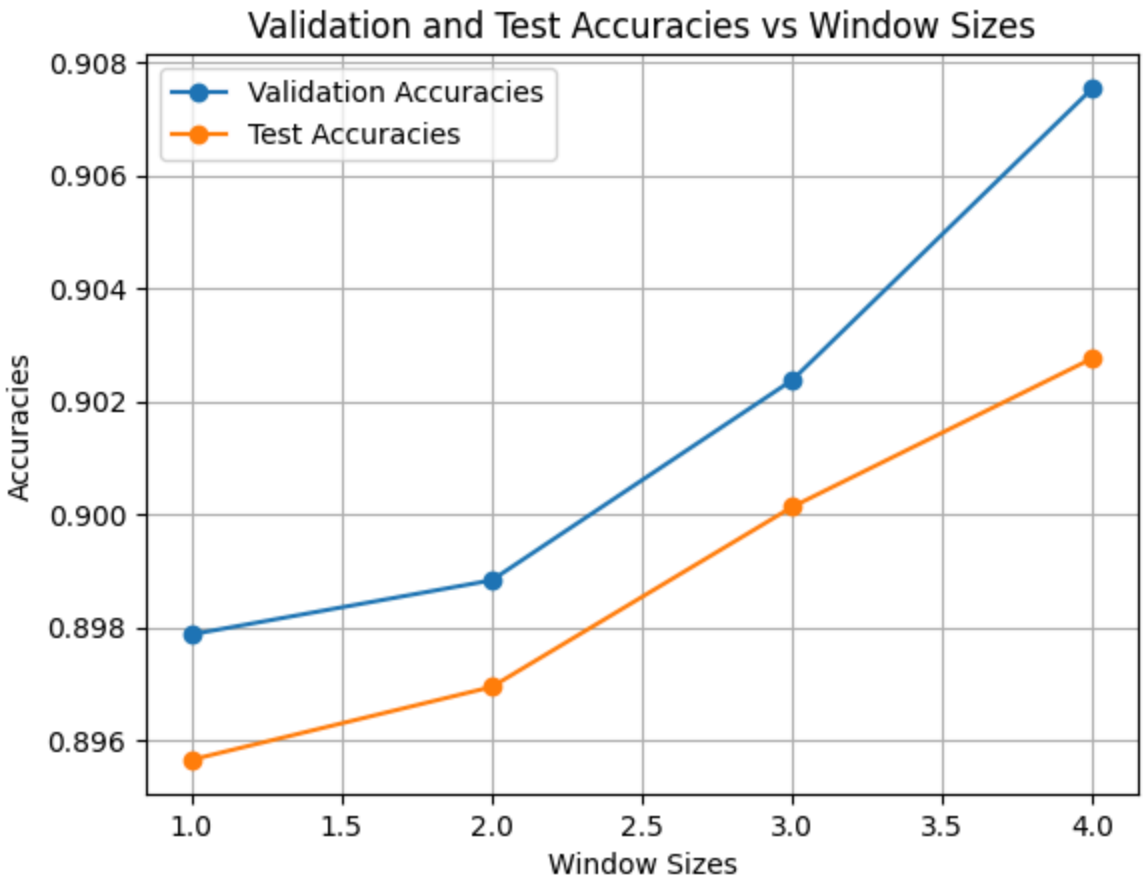
```
 0%|          | 0/5 [00:00<?, ?it/s]
1  train
eval

20%|██        | 1/5 [00:42<02:51, 42.92s/it]
Epoch 1/5, Training Loss: 0.5919394746422768, Validation Accuracy:
0.86575
2  train
eval

40%|████      | 2/5 [01:26<02:10, 43.40s/it]
Epoch 2/5, Training Loss: 0.3679844481696685, Validation Accuracy:
0.8753333333333333
3  train
eval

60%|██████    | 3/5 [02:10<01:27, 43.66s/it]
Epoch 3/5, Training Loss: 0.3090011770290633, Validation Accuracy:
0.8922916666666667
4  train
eval

80%|████████  | 4/5 [02:53<00:43, 43.51s/it]
Epoch 4/5, Training Loss: 0.2734802857674658, Validation Accuracy:
0.8970833333333333
5  train
eval

100%|██████████| 5/5 [03:36<00:00, 43.31s/it]

Epoch 5/5, Training Loss: 0.2461644219427059, Validation Accuracy:
0.8975416666666667

SL

val
100%|██████████| 750/750 [00:06<00:00, 116.56it/s]
```

Accuracy on the val set: 0.8975416666666667 for window_size = 4

Classification Report:

	precision	**recall**	**f1-score**	**support**

```
           0       0.94      0.87      0.90      5956
           1       0.93      0.98      0.95      6058
           2       0.87      0.86      0.86      5911
           3       0.86      0.88      0.87      6075

    accuracy                           0.90     24000
   macro avg       0.90      0.90      0.90     24000
weighted avg       0.90      0.90      0.90     24000

Confusion Matrix:
[[5196  263  263  234]
 [  44 5929   39   46]
 [ 175   94 5061  581]
 [ 137  109  474 5355]]
Micro Recall: 0.8975416666666667
Macro Recall: 0.8971963029452936
Micro F1 Score: 0.8975416666666667
Macro F1 Score: 0.8970517722873051


test
100%|██████████| 238/238 [00:02<00:00, 115.35it/s]

Accuracy on the test set: 0.9027631578947368 for window_size = 4
Classification Report:
              precision    recall  f1-score   support

           0       0.93      0.87      0.90      1900
           1       0.93      0.97      0.95      1900
           2       0.86      0.85      0.85      1900
           3       0.85      0.88      0.86      1900

    accuracy                           0.90      7600
   macro avg       0.90      0.90      0.90      7600
weighted avg       0.90      0.90      0.90      7600

Confusion Matrix:
[[1655   78   79   88]
 [  15 1848   24   13]
 [  62   27 1606  205]
 [  46   27  151 1676]]
Micro Recall: 0.9027631578947368
Macro Recall: 0.9027631578947368
Micro F1 Score: 0.9027631578947368
Macro F1 Score: 0.9025626745614392
```


Validation and Test Accuracies vs Window Sizes
Validation Accuracies
Test Accuracies
Accuracies
Window Sizes
0.908
0.906
0.904
0.902
0.900
0.898
0.896
1.0
1.5
2.0
2.5
3.0
3.5
4.0