Introduction to NLP (CS7.401)

Spring 2023,

IIIT Hyderabad

Assignment 2 Report

By

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Methodology:

- Extracted the dataset:

s	i	w	l	x	g	f	Tense	Degree	Poss	Type	Person	type	Gender	Case	Number	Mood
1	1	what	what	PRON	0	root	_	_	_	Int,Rel	_	Int,Rel	_	_	_	_
	2	is	be	AUX	1	cop	Pres	_	_	_	3	_	_	_	Sing	Ind
	3	the	the	DET	4	det	_	_	_	Art	_	Art	_	_	_	_
	4	cost	cost	NOUN	1	nsubj	_	_	_	_	_	_	_	_	Sing	_
	5	of	of	ADP	7	case	_	_	_	_	_	_	_	_	_	_
	6	a	a	DET	7	det	_	_	_	Art	_	Art	_	_	_	_
	7	round	round	NOUN	4	nmod	_	_	_	_	_	_	_	_	Sing	_
	8	trip	trip	NOUN	7	compound	_	_	_	_	_	_	_	_	Sing	_
	9	flight	flight	NOUN	7	nmod	_	_	_	_	_	_	_	_	Sing	_
	10	from	from	ADP	11	case	_	_	_	_	_	_	_	_	_	_
	11	pittsburgh	Pittsburgh	PROPN	9	nmod	_	_	_	_	_	_	_	_	Sing	_
	12	to	to	ADP	13	case	_	_	_	_	_	_	_	_	_	_
	13	atlanta	Atlanta	PROPN	9	nmod	_	_	_	_	_	_	_	_	Sing	_
	14	beginning	begin	VERB	9	nmod	Pres	_	_	_	_	_	_	_	_	_
	15	on	on	ADP	16	case	_	_	_	_	_	_	_	_	_	_
	16	april	April	NOUN	14	nmod	_	_	_	_	_	_	_	_	Sing	_
	17	twenty	twenty	NUM	16	nummod	_	_	_	Card	_	Card	_	_	_	_
	18	fifth	five	ADJ	17	compound	_	Pos	_	Ord	_	Ord	_	_	_	_
	19	and	and	CCONJ	20	cc	_	_	_	_	_	_	_	_	_	_
	20	returning	return	VERB	14	conj	Pres	_	_	_	_	_	_	_	_	_
	21	on	on	ADP	22	case	_	_	_	_	_	_	_	_	_	_
	22	may	May	NOUN	20	nmod	_	_	_	_	_	_	_	_	Sing	_
	23	sixth	six	ADJ	22	amod	_	Pos	_	Ord	_	Ord	_	_	_	_
2	1	now	now	ADV	3	advmod	_	Pos	_	_	_	_	_	_	_	_
	2	i	I	PRON	3	nsubj	_	_	_	Prs	1	Prs	_	Nom	Sing	_
	3	need	need	VERB	0	root	Pres	_	_	_	_	_	_	_	_	Ind
	4	a	a	DET	5	det	_	_	_	Art	_	Art	_	_	_	_
	5	flight	flight	NOUN	3	obj	_	_	_	_	_	_	_	_	Sing	_
	6	leaving	leave	VERB	5	acl	Pres									

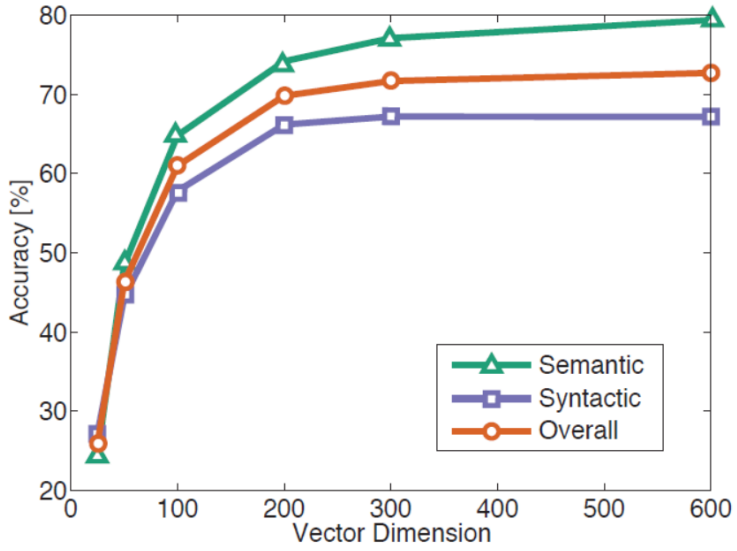
- Combine the Train, Test and VAlidation to create vocabulary
- Add more words in the vocabulary from glove embedding.
- Create model using LSTM
- Train model on different hyperparameters

Effect of hyperparameter tuning in POS tagging using LSTM

Effect of Embedding size:

For Glove Embedding :

According to the paper , accuracy of the model increases as we increase the dimension of embedding and this effect diminishes after a certain number . Similar results we observed here . As we increase the dimension of embedding accuracy slightly improves.



Effect of dropout:

Dropout is a regularization technique that is commonly used in neural networks, including LSTM networks, to prevent overfitting. It works by randomly dropping out (setting to zero) some fraction of the input units (neurons) during training, which forces the network to learn more robust features and reduces its dependence on any one input feature.

Here we observe that adding a little Dropout helps the model for better accuracy. This is because POS tagging models often have a large number of input features (such as word embeddings, previous tags, etc.), which can lead to overfitting if not properly regularized. But adding more dropouts might make the model underfit. Although here the model accuracy slightly improved as we increased the dropout from 0.2 to 0.8.

Effect of LSTM Node:

Increasing the number of LSTM nodes in the model generally increases its capacity to capture more complex relationships between words and their corresponding POS tags, leading to better accuracy. However, increasing the number of nodes also increases the complexity of the model, which can lead to overfitting on the training data and poor generalization to new data. Here we observe that Accuracy almost remains the same as we change the LSTM nodes from 128 to 64.

Effect of learning rate:

If the learning rate is set too high, the model may overshoot the optimal parameters and fail to converge to the global minimum of the loss function. This can result in unstable training and poor performance on the validation set.

On the other hand, if the learning rate is set too low, the model may converge very slowly, which can result in longer training times and suboptimal performance. Here we observe that changing the learning rate from 0.001 to 0.0001 makes the model take slightly more time and accuracy almost remains the same.

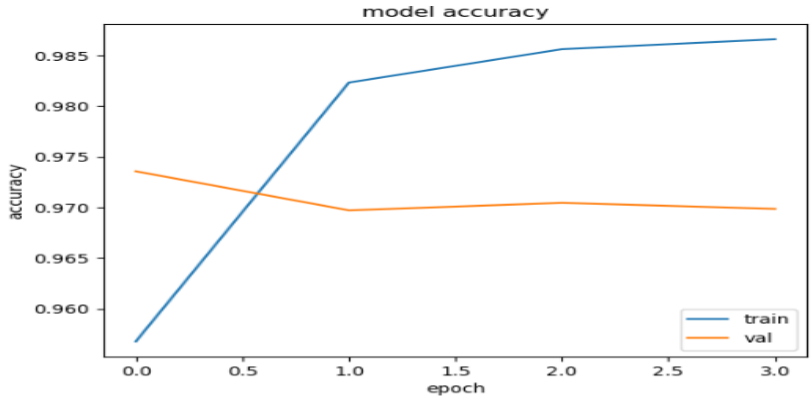
Effect of Number of layers:

Generally, adding more LSTM layers to a POS tagging model improves its ability to capture complex patterns and dependencies in the input data, leading to better performance on the task. However, this improvement may decrease after a certain number of layers, as adding too many layers can make the model more prone to overfitting and result in higher computational cost. Here we observe that accuracy increases slightly as we change the number of LSTM layers from 1 to 2.

Details of all the models

Model 1:

Embedding size	**300**
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**1**



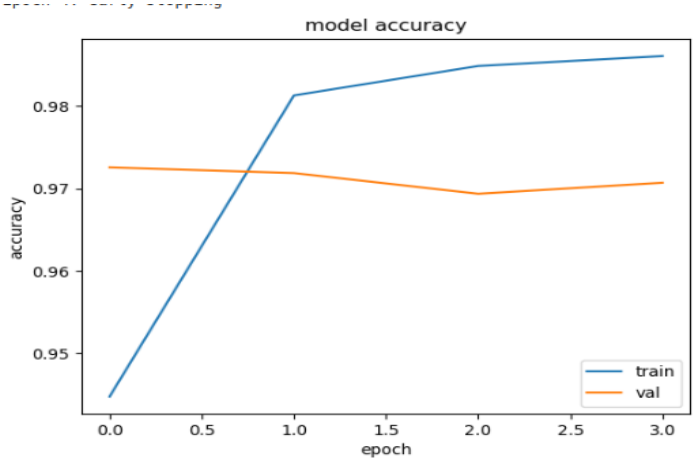

```
206/206 [==============================] - 2s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.94      0.91      0.92      1928
         det       0.98      0.89      0.93      6710
         adv       0.94      0.77      0.85      1025
        pron       0.87      0.97      0.92      5162
       cconj       0.99      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.96      0.99      0.97      3374
         adj       0.89      0.94      0.91      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.96      0.96      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.96     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 2

Embedding size	**300**

6

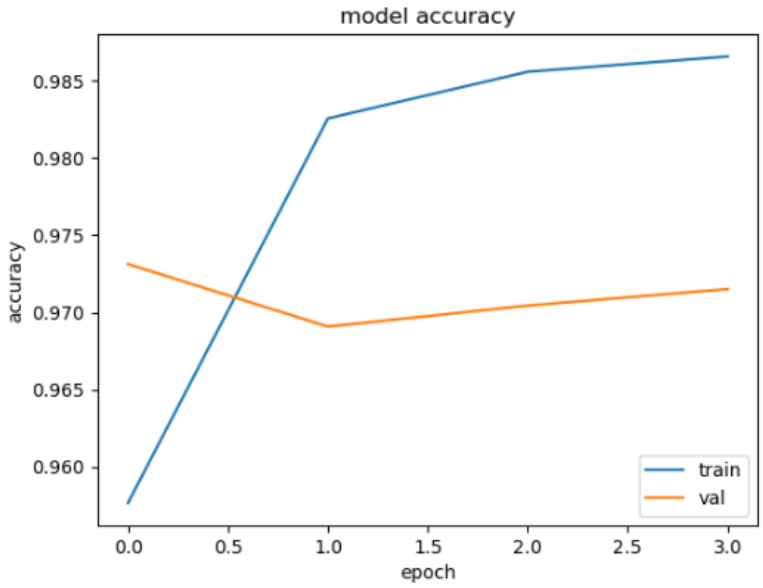
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.98      0.99      8396
         num       0.91      0.93      0.92      1928
         det       0.98      0.89      0.93      6710
         adv       0.97      0.82      0.89      1025
        pron       0.87      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.97      0.98      0.97      3374
         adj       0.92      0.92      0.92      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.96      0.97       904

    accuracy                           0.98     84416
   macro avg       0.97      0.96      0.96     84416
weighted avg       0.98      0.98      0.98     84416
```

Model 3

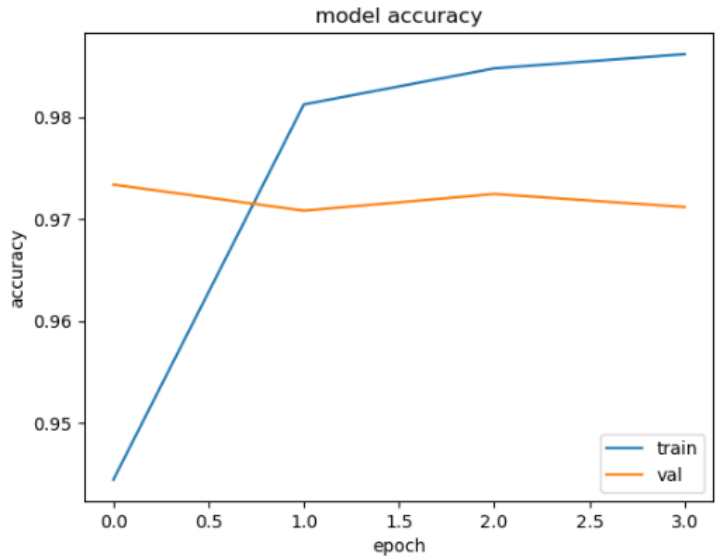
Embedding size	**300**
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.0001**
Number of layers	**1**




```
206/206 [==============================] - 3s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.97      0.98      8396
         num       0.93      0.93      0.93      1928
         det       0.97      0.89      0.93      6710
         adv       0.94      0.77      0.85      1025
        pron       0.87      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.98      0.97      0.98      3374
         adj       0.88      0.93      0.90      3092
         adp       1.00      0.99      0.99     18228
        intj       1.00      0.98      0.99       455
        part       0.97      0.96      0.97       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 4

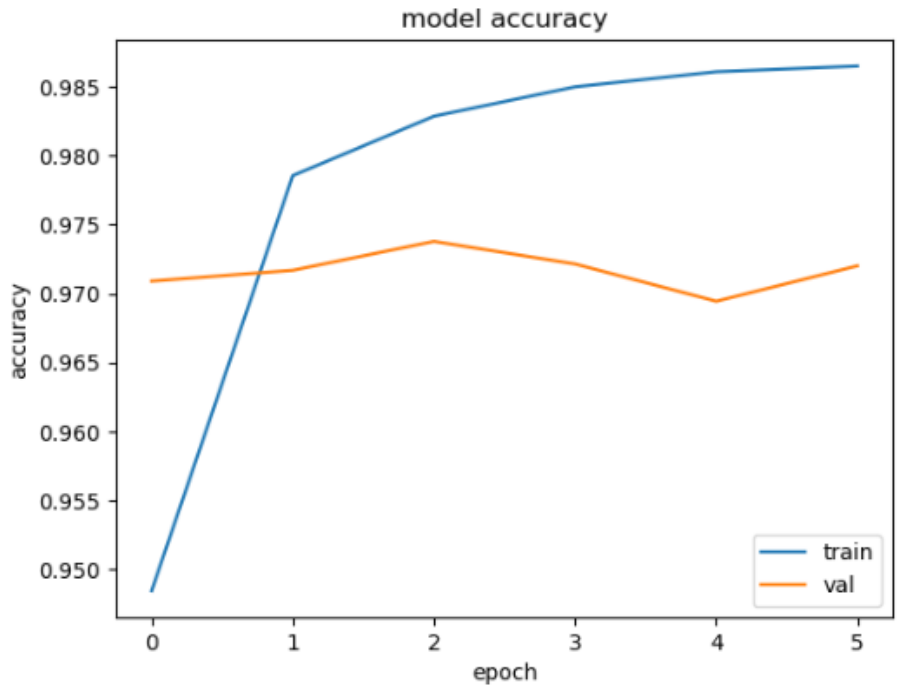
Embedding size	**300**
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 4s 6ms/step
              precision    recall  f1-score   support

       propn       0.99      1.00      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.93      0.93      0.93      1928
         det       0.97      0.89      0.93      6710
         adv       0.98      0.77      0.86      1025
        pron       0.87      0.97      0.92      5162
       cconj       0.99      1.00      1.00      1594
        noun       0.99      0.98      0.99     14647
         aux       0.97      0.98      0.97      3374
         adj       0.88      0.94      0.91      3092
         adp       1.00      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.96      0.97       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.96     84416
weighted avg       0.98      0.97      0.97     84416
```

Model 5

Embedding size	**300**
Dropout	**0.2**
LSTM Nodes	**64**
Learning rate	**0.001**
Number of layers	**1**

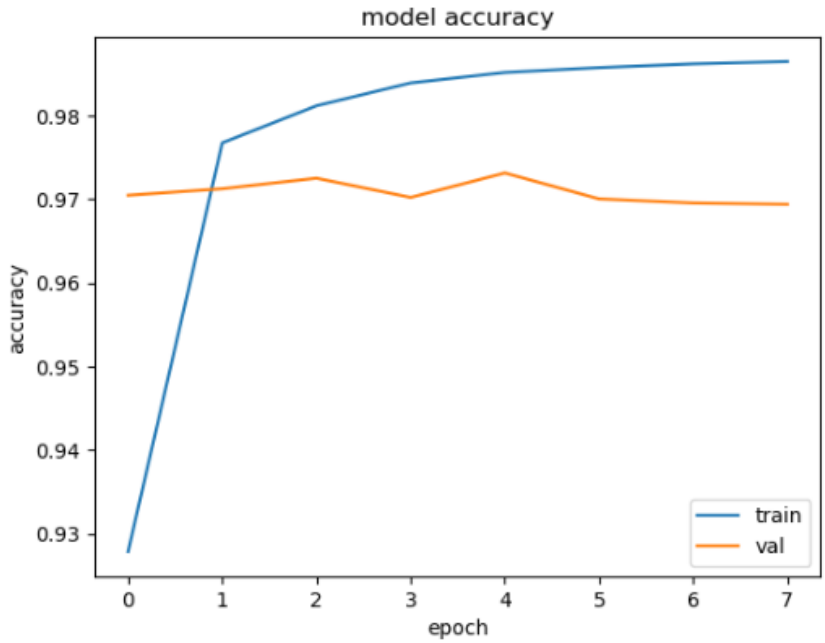



```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

        propn       0.99      0.99      0.99     18901
         verb       0.99      0.97      0.98      8396
          num       0.93      0.92      0.92      1928
          det       0.97      0.89      0.93      6710
          adv       0.96      0.83      0.89      1025
         pron       0.87      0.96      0.91      5162
        cconj       1.00      1.00      1.00      1594
         noun       0.99      0.99      0.99     14647
          aux       0.97      0.97      0.97      3374
          adj       0.92      0.95      0.93      3092
          adp       0.99      0.99      0.99     18228
         intj       1.00      1.00      1.00       455
         part       0.92      0.96      0.94       904

     accuracy                           0.97     84416
    macro avg       0.96      0.96      0.96     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 6

Embedding size	**300**
Dropout	**0.2**
LSTM Nodes	**64**

Learning rate	**0.001**
Number of layers	**2**



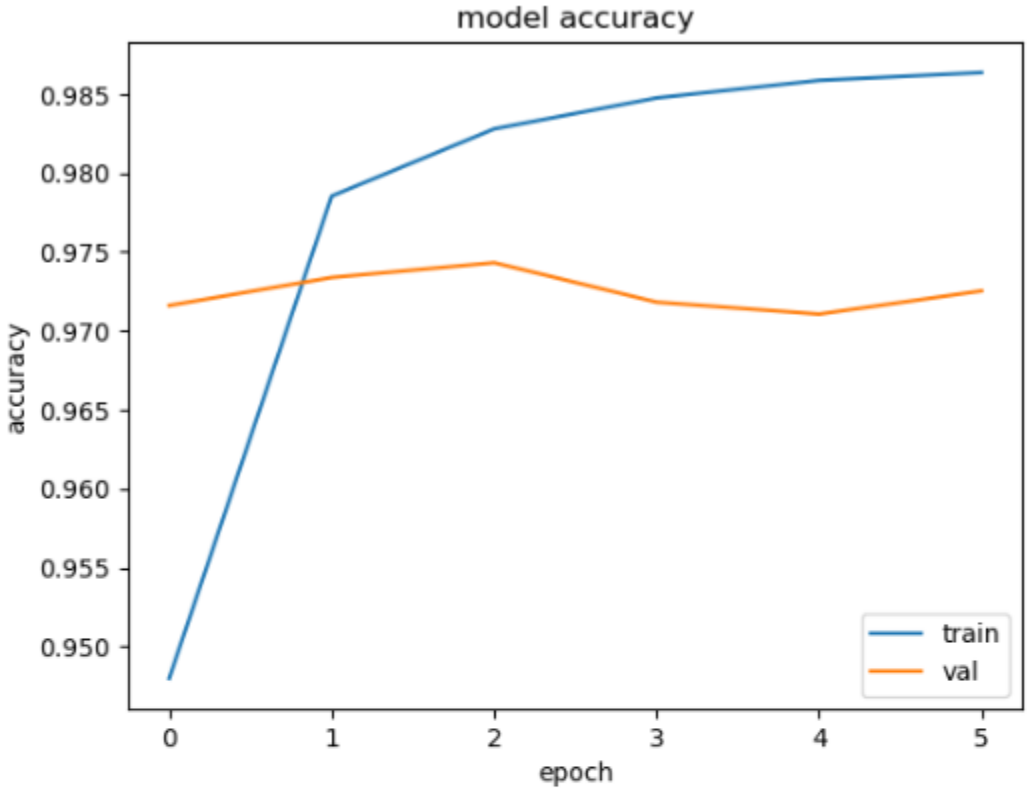

```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

        propn       0.99      0.99      0.99     18901
         verb       0.99      0.98      0.98      8396
          num       0.90      0.91      0.90      1928
          det       0.98      0.89      0.93      6710
          adv       0.87      0.77      0.82      1025
         pron       0.87      0.97      0.92      5162
        cconj       1.00      1.00      1.00      1594
         noun       0.98      0.99      0.99     14647
          aux       0.98      0.98      0.98      3374
          adj       0.90      0.91      0.90      3092
          adp       0.99      1.00      0.99     18228
         intj       1.00      0.98      0.99       455
         part       0.97      0.95      0.96       904

     accuracy                           0.97     84416
    macro avg       0.96      0.95      0.95     84416
 weighted avg       0.97      0.97      0.97     84416
```

Model 7

Embedding size	**300**
Dropout	**0.2**
LSTM Nodes	**64**

11

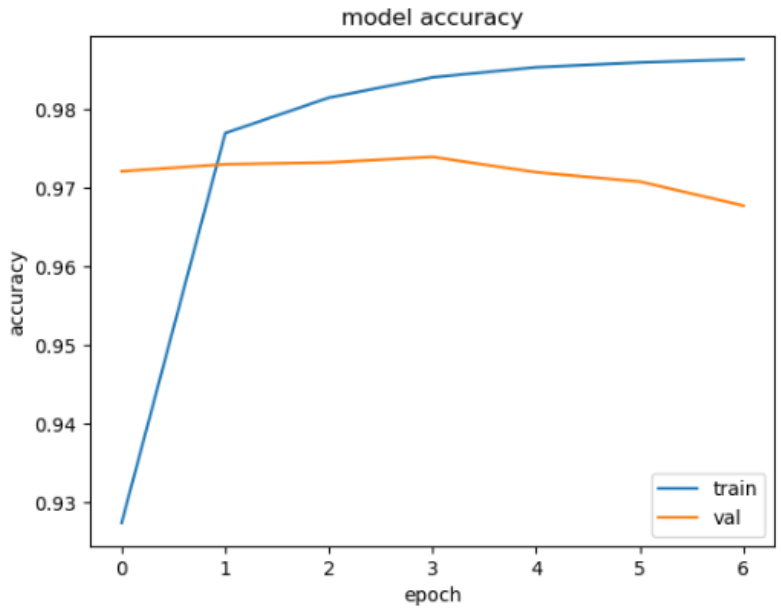
Learning rate	**0.0001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      1.00      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.94      0.93      0.93      1928
         det       0.98      0.89      0.93      6710
         adv       0.95      0.80      0.87      1025
        pron       0.87      0.97      0.92      5162
       cconj       0.99      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.96      0.99      0.98      3374
         adj       0.90      0.92      0.91      3092
         adp       1.00      0.99      0.99     18228
        intj       1.00      0.96      0.98       455
        part       0.97      0.95      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.96     84416
weighted avg       0.98      0.97      0.97     84416
```

Model 8

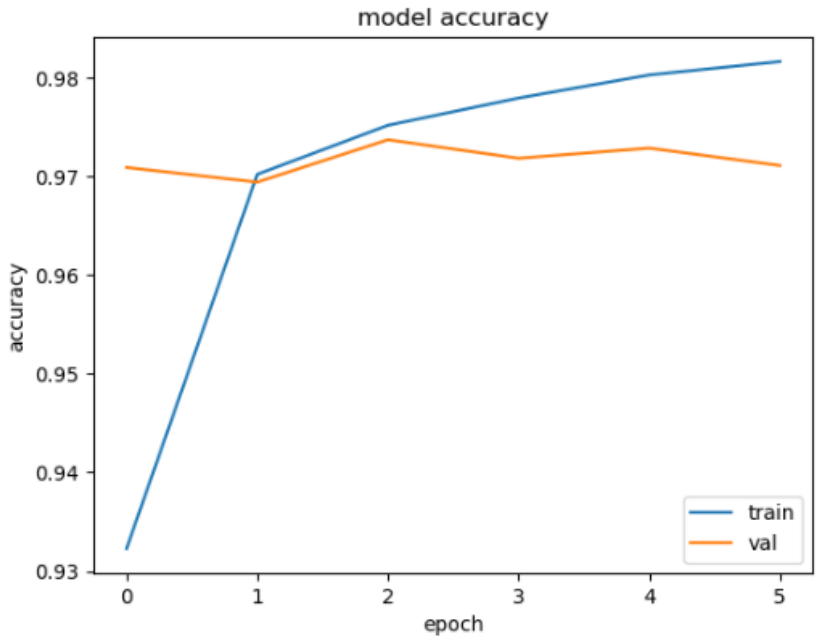
Embedding size	**300**
Dropout	**0.2**
LSTM Nodes	**64**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      1.00      0.99     18901
        verb       0.98      0.99      0.98      8396
         num       0.90      0.94      0.92      1928
         det       0.97      0.89      0.93      6710
         adv       0.93      0.91      0.92      1025
        pron       0.87      0.97      0.92      5162
       cconj       1.00      0.99      0.99      1594
        noun       0.99      0.99      0.99     14647
         aux       1.00      0.97      0.98      3374
         adj       0.91      0.90      0.90      3092
         adp       1.00      1.00      1.00     18228
        intj       1.00      1.00      1.00       455
        part       0.99      0.94      0.96       904

    accuracy                           0.98     84416
   macro avg       0.96      0.96      0.96     84416
weighted avg       0.98      0.98      0.98     84416
```

Model 9

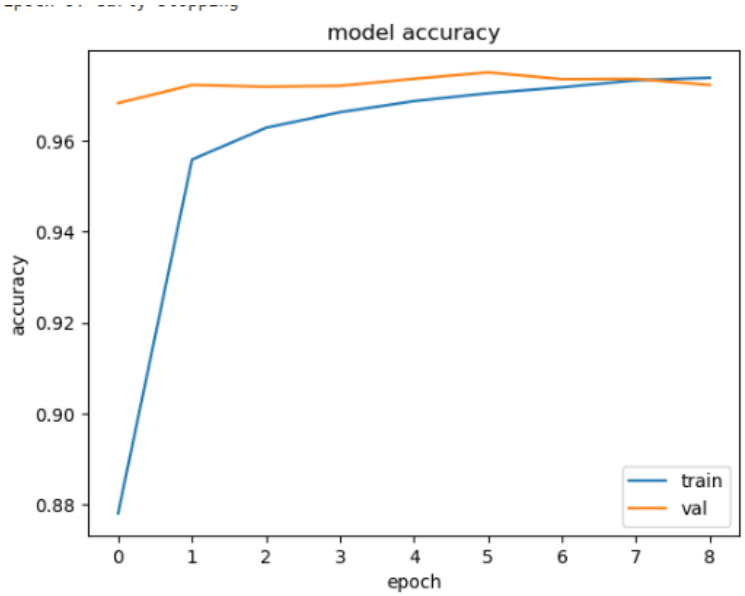
Embedding size	**300**
Dropout	**0.8**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.95      0.92      0.93      1928
         det       0.98      0.89      0.93      6710
         adv       0.93      0.84      0.88      1025
        pron       0.86      0.97      0.91      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.98      0.99      0.99     14647
         aux       0.97      0.99      0.98      3374
         adj       0.91      0.95      0.93      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.95      0.96       904

    accuracy                           0.98     84416
   macro avg       0.96      0.96      0.96     84416
weighted avg       0.98      0.98      0.98     84416
```

Model 10

Embedding size	**300**
Dropout	**0.8**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**2**

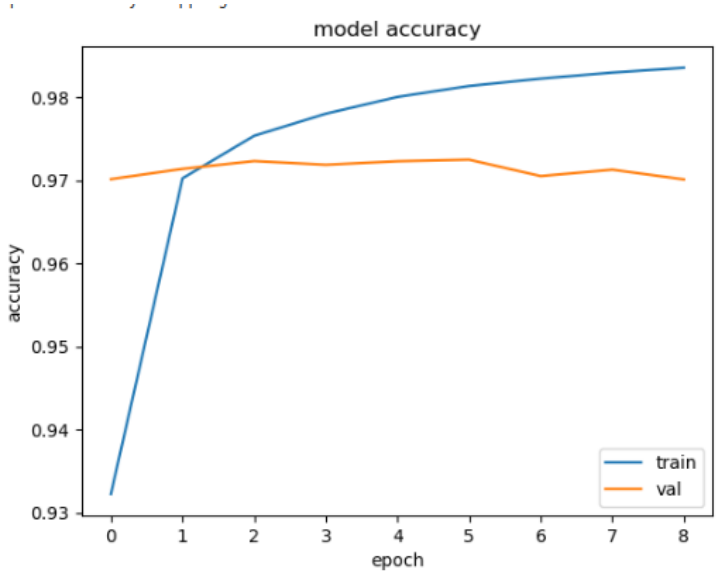



```
206/206 [==============================] - 3s 5ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.92      0.94      0.93      1928
         det       0.98      0.90      0.94      6710
         adv       0.97      0.78      0.86      1025
        pron       0.88      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.98      0.99      0.99     14647
         aux       0.98      0.97      0.98      3374
         adj       0.92      0.94      0.93      3092
         adp       1.00      1.00      1.00     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.95      0.96       904

    accuracy                           0.98     84416
   macro avg       0.97      0.96      0.96     84416
weighted avg       0.98      0.98      0.98     84416
```

Model 11

Embedding size	**300**
Dropout	**0.8**

LSTM Nodes	128
Learning rate	0.0001
Number of layers	1

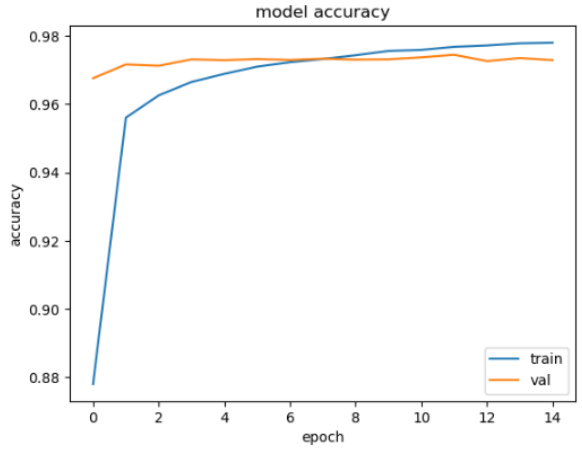



```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.98      0.98      8396
         num       0.94      0.93      0.94      1928
         det       0.98      0.89      0.93      6710
         adv       0.98      0.71      0.83      1025
        pron       0.87      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.99      0.97      0.98      3374
         adj       0.90      0.94      0.92      3092
         adp       0.99      1.00      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.95      0.91      0.93       904

    accuracy                           0.97     84416
   macro avg       0.97      0.95      0.95     84416
weighted avg       0.98      0.97      0.97     84416
```

Model 12

Embedding size	300
Dropout	0.8

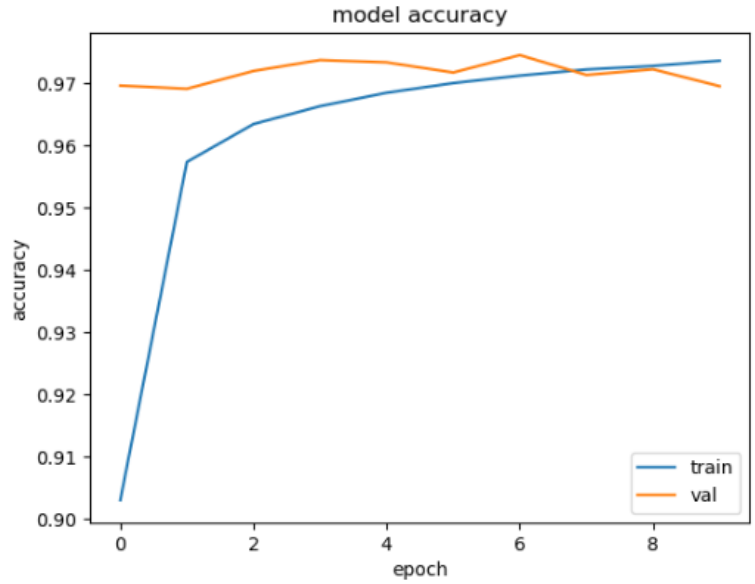
LSTM Nodes	**128**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 4s 6ms/step
              precision    recall  f1-score   support

        propn       0.99      0.99      0.99     18901
         verb       0.99      0.97      0.98      8396
          num       0.92      0.92      0.92      1928
          det       0.98      0.89      0.93      6710
          adv       0.97      0.80      0.87      1025
         pron       0.87      0.97      0.92      5162
        cconj       1.00      1.00      1.00      1594
         noun       0.98      0.99      0.99     14647
          aux       0.97      0.99      0.98      3374
          adj       0.89      0.94      0.92      3092
          adp       0.99      1.00      1.00     18228
         intj       1.00      1.00      1.00       455
         part       0.97      0.95      0.96       904

     accuracy                           0.97     84416
    macro avg       0.96      0.95      0.96     84416
 weighted avg       0.98      0.97      0.97     84416
```

Model 13

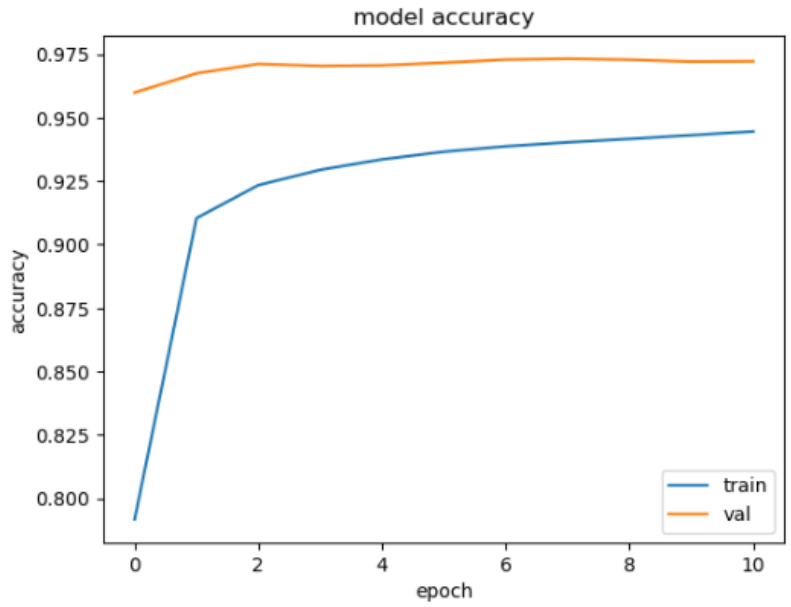
Embedding size	**300**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.94      0.94      0.94      1928
         det       0.99      0.88      0.93      6710
         adv       0.95      0.86      0.90      1025
        pron       0.87      0.98      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.97      0.98      0.98      3374
         adj       0.93      0.95      0.94      3092
         adp       0.99      1.00      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.99      0.91      0.95       904

    accuracy                           0.98     84416
   macro avg       0.97      0.96      0.96     84416
weighted avg       0.98      0.98      0.98     84416
```

Model 14

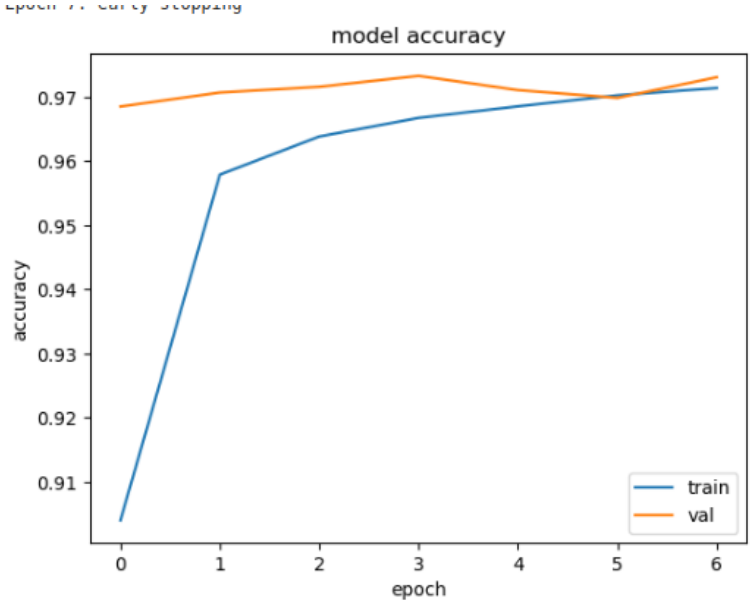
Embedding size	**300**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      1.00      0.99     18901
        verb       0.99      0.96      0.97      8396
         num       0.90      0.92      0.91      1928
         det       0.97      0.89      0.93      6710
         adv       0.98      0.69      0.81      1025
        pron       0.87      0.96      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.92      0.99      0.96      3374
         adj       0.90      0.93      0.92      3092
         adp       0.99      1.00      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.98      0.95      0.97       904

    accuracy                           0.97     84416
   macro avg       0.96      0.94      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 15

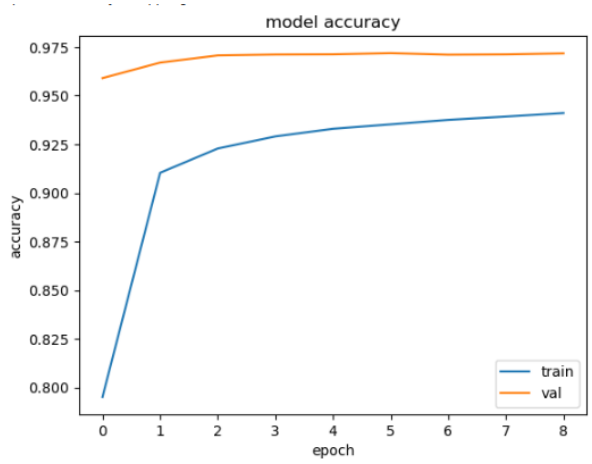
Embedding size	**300**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.0001**
Number of layers	**1**




```
206/206 [==============================] - 3s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.98      0.98      8396
         num       0.93      0.90      0.92      1928
         det       0.98      0.90      0.94      6710
         adv       0.97      0.79      0.87      1025
        pron       0.88      0.98      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.98      0.96      0.97      3374
         adj       0.89      0.95      0.92      3092
         adp       1.00      1.00      1.00     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.95      0.96       904

    accuracy                           0.98     84416
   macro avg       0.97      0.95      0.96     84416
weighted avg       0.98      0.98      0.98     84416
```

Model 16

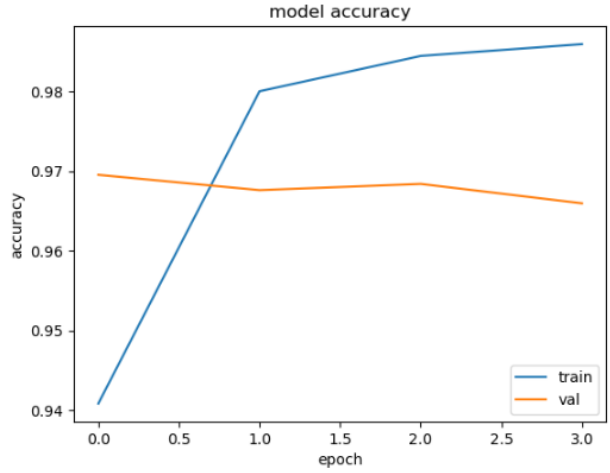
Embedding size	**300**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.95      0.97      8396
         num       0.94      0.93      0.93      1928
         det       0.98      0.90      0.94      6710
         adv       0.94      0.69      0.80      1025
        pron       0.88      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.92      1.00      0.96      3374
         adj       0.90      0.95      0.93      3092
         adp       0.99      1.00      1.00     18228
        intj       1.00      1.00      1.00       455
        part       0.98      0.95      0.97       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 17

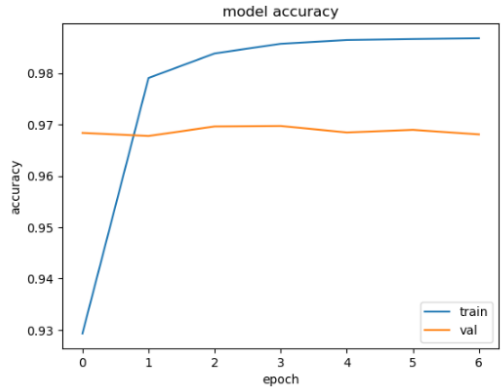
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.90      0.94      0.92      1928
         det       0.97      0.88      0.92      6710
         adv       0.95      0.81      0.88      1025
        pron       0.87      0.96      0.91      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.98      0.99     14647
         aux       0.96      0.98      0.97      3374
         adj       0.89      0.93      0.91      3092
         adp       0.99      1.00      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.99      0.92      0.95       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.96     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 18

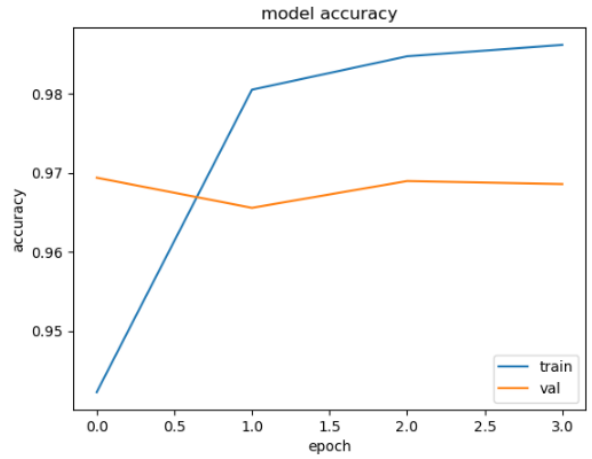
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**2**




```
206/206 [==============================] - 5s 5ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.98      0.98      8396
         num       0.91      0.92      0.92      1928
         det       0.98      0.89      0.93      6710
         adv       0.90      0.78      0.84      1025
        pron       0.87      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.97      0.99      0.98      3374
         adj       0.91      0.91      0.91      3092
         adp       0.99      1.00      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.93      0.95       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 19

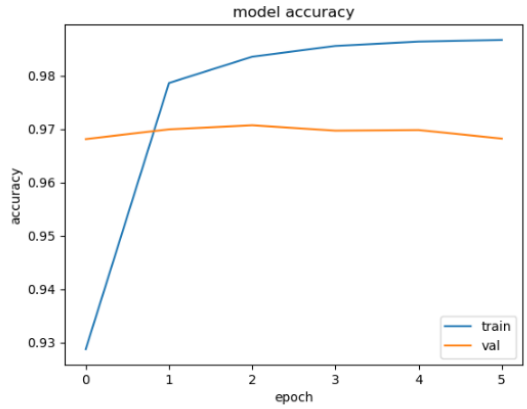
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.0001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.99      0.98      8396
         num       0.92      0.90      0.91      1928
         det       0.97      0.88      0.92      6710
         adv       0.96      0.75      0.84      1025
        pron       0.87      0.96      0.91      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.98      0.98      0.98     14647
         aux       0.99      0.96      0.97      3374
         adj       0.85      0.94      0.89      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.95      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 20

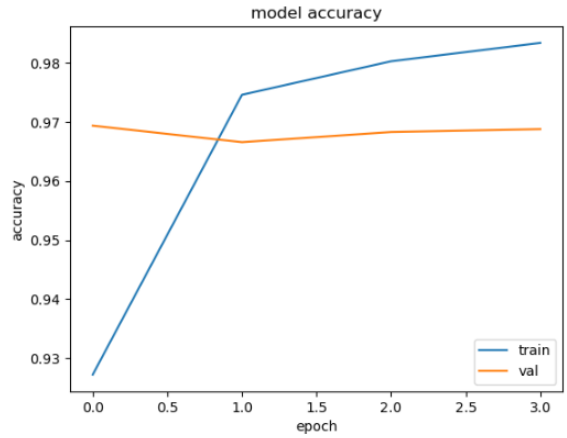
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**128**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 4s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.99      0.98      8396
         num       0.91      0.94      0.92      1928
         det       0.97      0.88      0.92      6710
         adv       0.98      0.74      0.85      1025
        pron       0.87      0.96      0.91      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.98      0.97      0.98      3374
         adj       0.90      0.93      0.92      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.96      0.96      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 21

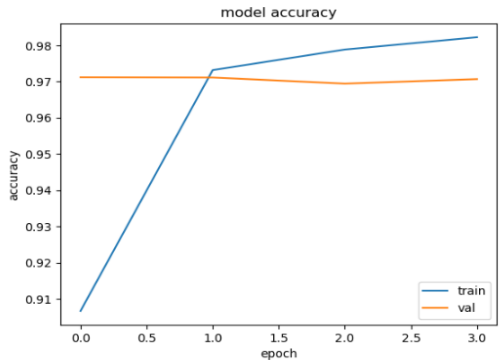
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**64**
Learning rate	**0.001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.98      0.98      8396
         num       0.91      0.93      0.92      1928
         det       0.98      0.88      0.93      6710
         adv       0.92      0.76      0.83      1025
        pron       0.86      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.96      0.97      0.97      3374
         adj       0.89      0.92      0.90      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.96      0.97       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 22

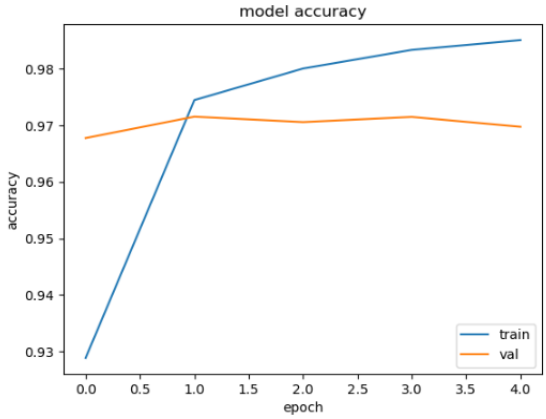
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**64**
Learning rate	**0.001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.97      0.98      8396
         num       0.92      0.93      0.92      1928
         det       0.97      0.90      0.93      6710
         adv       0.96      0.72      0.83      1025
        pron       0.86      0.96      0.91      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.96      0.99      0.97      3374
         adj       0.91      0.92      0.91      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.96      0.97       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 23

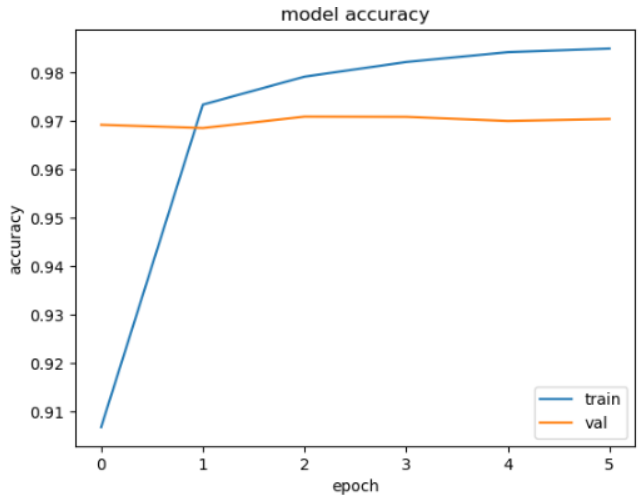
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**64**
Learning rate	**0.0001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.98      0.98      8396
         num       0.89      0.94      0.92      1928
         det       0.97      0.89      0.93      6710
         adv       0.96      0.70      0.81      1025
        pron       0.87      0.97      0.92      5162
       cconj       0.99      1.00      1.00      1594
        noun       0.98      0.99      0.99     14647
         aux       0.97      0.96      0.96      3374
         adj       0.90      0.91      0.90      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.95      0.95      0.95       904

    accuracy                           0.97     84416
   macro avg       0.96      0.94      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 24

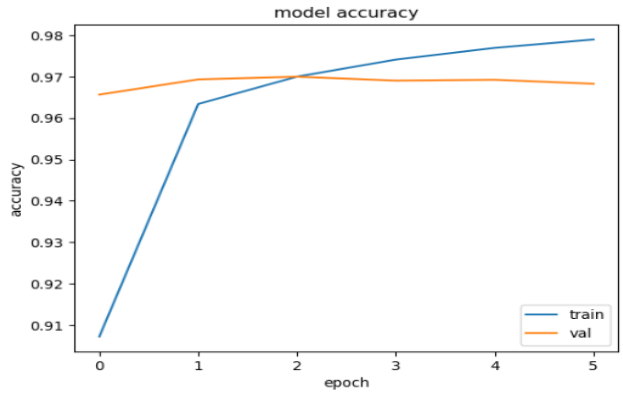
Embedding size	**128**
Dropout	**0.2**
LSTM Nodes	**64**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.98      0.98      8396
         num       0.91      0.90      0.91      1928
         det       0.97      0.89      0.93      6710
         adv       0.97      0.78      0.87      1025
        pron       0.87      0.97      0.92      5162
       cconj       0.99      1.00      0.99      1594
        noun       0.99      0.99      0.99     14647
         aux       0.98      0.97      0.98      3374
         adj       0.88      0.92      0.90      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.94      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 25

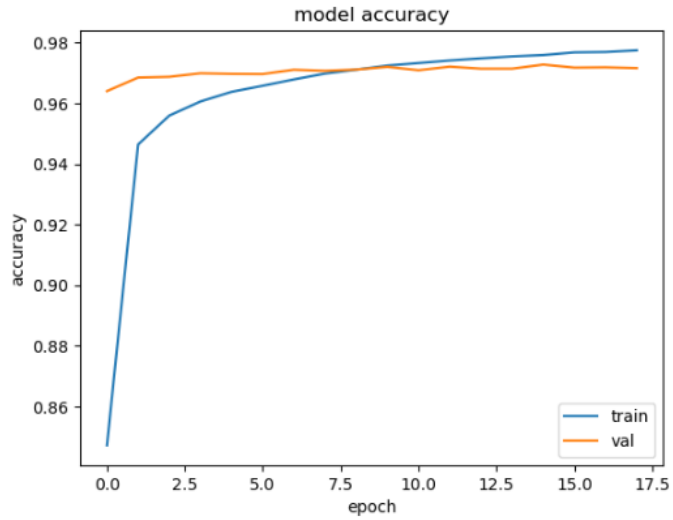
Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

        propn       0.99      0.99      0.99     18901
         verb       0.99      0.97      0.98      8396
          num       0.91      0.94      0.93      1928
          det       0.97      0.89      0.93      6710
          adv       0.94      0.79      0.86      1025
         pron       0.87      0.97      0.91      5162
        cconj       0.99      1.00      1.00      1594
         noun       0.98      0.98      0.98     14647
          aux       0.96      0.99      0.97      3374
          adj       0.86      0.92      0.89      3092
          adp       0.99      0.99      0.99     18228
         intj       1.00      0.98      0.99       455
         part       0.97      0.94      0.96       904

     accuracy                           0.97     84416
    macro avg       0.96      0.95      0.95     84416
 weighted avg       0.97      0.97      0.97     84416
```

Model 26

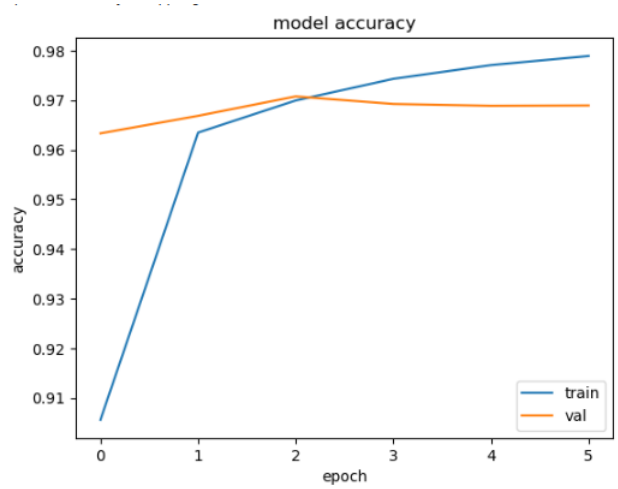
Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**128**
Learning rate	**0.001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.97      0.98      8396
         num       0.89      0.94      0.91      1928
         det       0.97      0.89      0.93      6710
         adv       0.89      0.77      0.83      1025
        pron       0.86      0.97      0.91      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.99      0.99      0.99     14647
         aux       0.96      0.98      0.97      3374
         adj       0.91      0.91      0.91      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.96      0.97       904

    accuracy                           0.97     84416
   macro avg       0.95      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 27

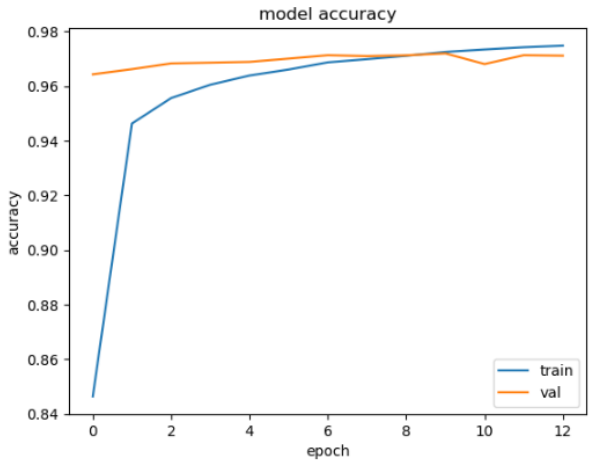
Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**128**
Learning rate	**0.0001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.97      0.98      8396
         num       0.92      0.89      0.90      1928
         det       0.97      0.89      0.93      6710
         adv       0.95      0.76      0.84      1025
        pron       0.87      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.98      0.99      0.99     14647
         aux       0.96      0.99      0.97      3374
         adj       0.87      0.93      0.90      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.94      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 28

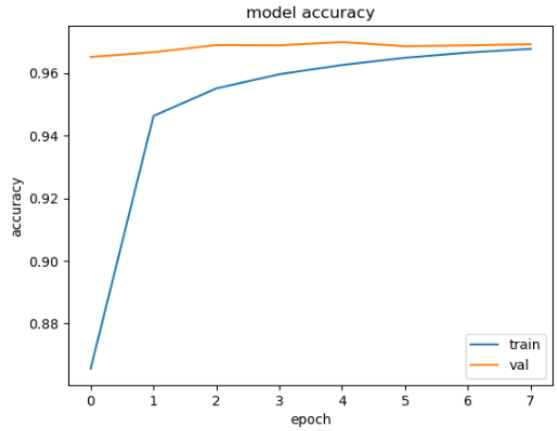
Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**128**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

        propn       0.99      0.99      0.99     18901
         verb       0.98      0.98      0.98      8396
          num       0.91      0.92      0.92      1928
          det       0.98      0.89      0.94      6710
          adv       0.98      0.75      0.85      1025
         pron       0.87      0.98      0.92      5162
        cconj       1.00      1.00      1.00      1594
         noun       0.99      0.99      0.99     14647
          aux       0.96      0.98      0.97      3374
          adj       0.88      0.93      0.91      3092
          adp       0.99      0.99      0.99     18228
         intj       1.00      1.00      1.00       455
         part       0.97      0.94      0.96       904

     accuracy                           0.97     84416
    macro avg       0.96      0.95      0.95     84416
 weighted avg       0.97      0.97      0.97     84416
```

Model 29

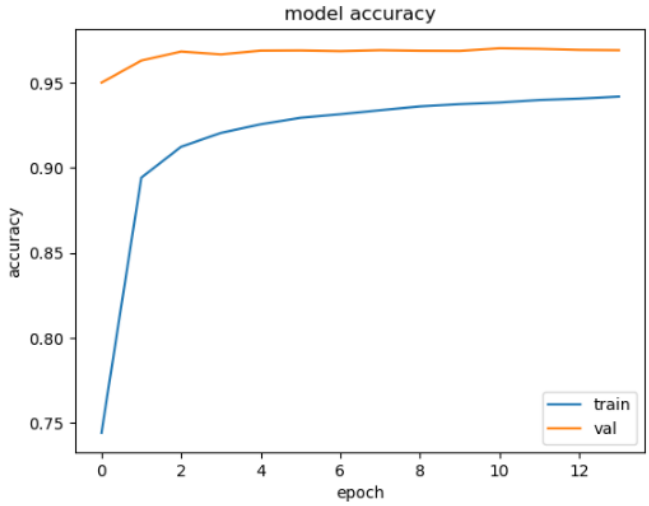
Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.001**
Number of layers	**1**




```
206/206 [==============================] - 2s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.98      0.98      8396
         num       0.93      0.92      0.92      1928
         det       0.97      0.89      0.93      6710
         adv       0.96      0.73      0.83      1025
        pron       0.87      0.97      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.98      0.99      0.99     14647
         aux       0.98      0.99      0.98      3374
         adj       0.88      0.96      0.92      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.94      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 30

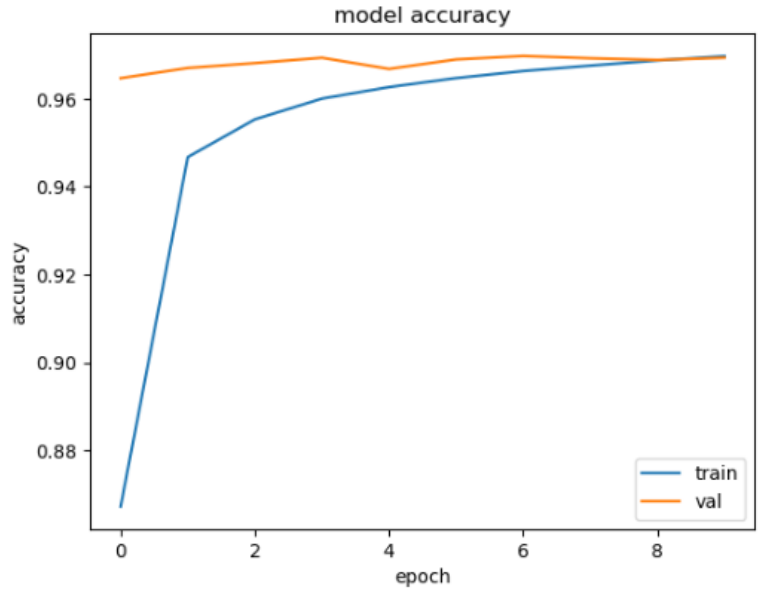
Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.001**
Number of layers	**2**




```
206/206 [==============================] - 3s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.98      0.97      0.97      8396
         num       0.93      0.93      0.93      1928
         det       0.97      0.89      0.93      6710
         adv       0.96      0.65      0.78      1025
        pron       0.87      0.96      0.91      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.98      0.99      0.99     14647
         aux       0.95      0.95      0.95      3374
         adj       0.88      0.94      0.91      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.95      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.94      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```

Model 31

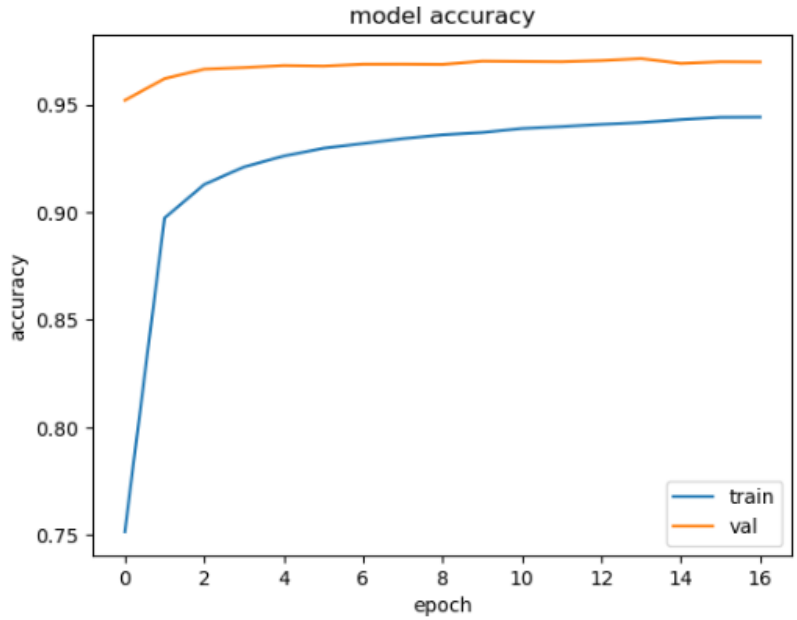
Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.0001**
Number of layers	**1**




```
206/206 [==============================] - 2s 3ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.97      0.98      8396
         num       0.91      0.95      0.93      1928
         det       0.99      0.89      0.94      6710
         adv       0.93      0.78      0.85      1025
        pron       0.86      0.98      0.92      5162
       cconj       1.00      1.00      1.00      1594
        noun       0.98      0.99      0.99     14647
         aux       0.97      0.98      0.98      3374
         adj       0.94      0.93      0.94      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.98      0.93      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.96     84416
weighted avg       0.98      0.97      0.97     84416
```

Model 32

Embedding size	**128**
Dropout	**0.8**
LSTM Nodes	**64**
Learning rate	**0.0001**
Number of layers	**2**




```
206/206 [==============================] - 6s 4ms/step
              precision    recall  f1-score   support

       propn       0.99      0.99      0.99     18901
        verb       0.99      0.95      0.97      8396
         num       0.91      0.96      0.93      1928
         det       0.98      0.90      0.94      6710
         adv       0.94      0.73      0.83      1025
        pron       0.87      0.98      0.92      5162
       cconj       0.99      1.00      0.99      1594
        noun       0.98      0.99      0.99     14647
         aux       0.92      0.99      0.96      3374
         adj       0.95      0.95      0.95      3092
         adp       0.99      0.99      0.99     18228
        intj       1.00      1.00      1.00       455
        part       0.97      0.94      0.96       904

    accuracy                           0.97     84416
   macro avg       0.96      0.95      0.95     84416
weighted avg       0.97      0.97      0.97     84416
```