Sentiment Analysis for Financial Market Signals

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Agenda

1. Background
2. Dataset
3. Model
    a. BOW
    b. BERT
    c. BERT transfer learning
4. Discussions
5. Improvement

Background

How many of you have heard about WallStreetBets?

- Short Squeeze: Condition that triggers a stock to increase rapidly

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Twitter

- Influencer
- Language
- Slangs
- Abbreviations

Dataset

Dataset name: Sentiment 140

targets: popularity of the tweet
ids: id of the tweet
date: date of the tweet
flag: query (lyx)
user: user of the tweet
text: content of the tweet

Sentiment	Count
Positive	800,000
Negative	800,000

Source: Kaggle.com

Dataset name: Financial sentiment

sentence: Tweets
sentiment: positive/negative/neutral

Sentiment	Count
Positive	1,852
Neutral	3,130
Negative	860

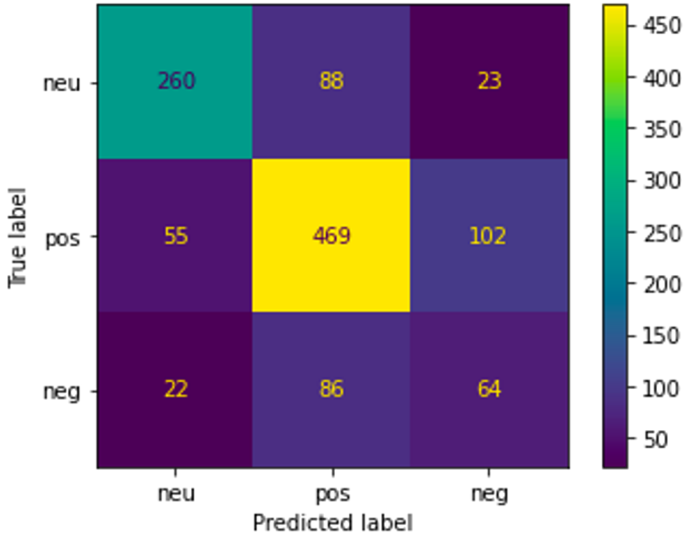
Bag-of-words (BOW)

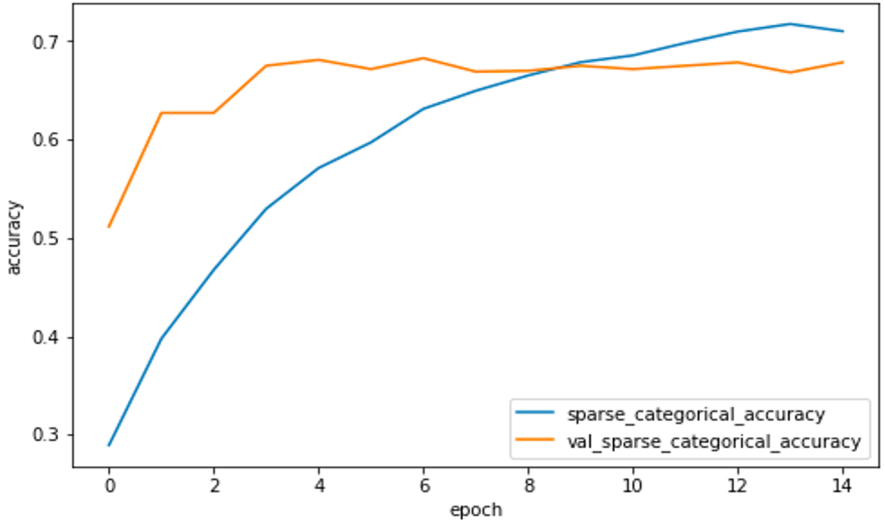
- 4 dense layers
- 3 dropout layers
  - Prevent overfitting
- 772,565 trainable parameters

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 6000)]	0
dense (Dense)	(None, 128)	768128
dropout (Dropout)	(None, 128)	0
dense_1 (Dense)	(None, 32)	4128
dropout_1 (Dropout)	(None, 32)	0
dense_2 (Dense)	(None, 8)	264
dropout_2 (Dropout)	(None, 8)	0
dense_3 (Dense)	(None, 5)	45

Model Performance

- F1 score: 0.681
- Accuracy: 67.84%





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BERT without Fine Tuning

- 4 dense layers
- No dropout layers
- Trainable parameters: 246,917

Layer (type)	Output Shape	Param #	Connected to
input_ids (InputLayer)	[(None, 100)]	0	[]
token_type_ids (InputLayer)	[(None, 100)]	0	[]
attention_mask (InputLayer)	[(None, 100)]	0	[]
bert (TFBertMainLayer)	TFBaseModelOutputWithPoolingAndCrossAttentions(last_hidden_state=(None, 100, 768), pooler_output=(None, 768), past_key_values=None, hidden_states=None, attentions=None, cross_attentions=None)	108310272	['input_ids[0][0]', 'token_type_ids[0][0]', 'attention_mask[0][0]']
dense_4 (Dense)	(None, 256)	196864	['bert[1][1]']
dense_5 (Dense)	(None, 128)	32896	['dense_4[0][0]']
dense_6 (Dense)	(None, 128)	16512	['dense_5[0][0]']
dense_7 (Dense)	(None, 5)	645	['dense_6[0][0]']

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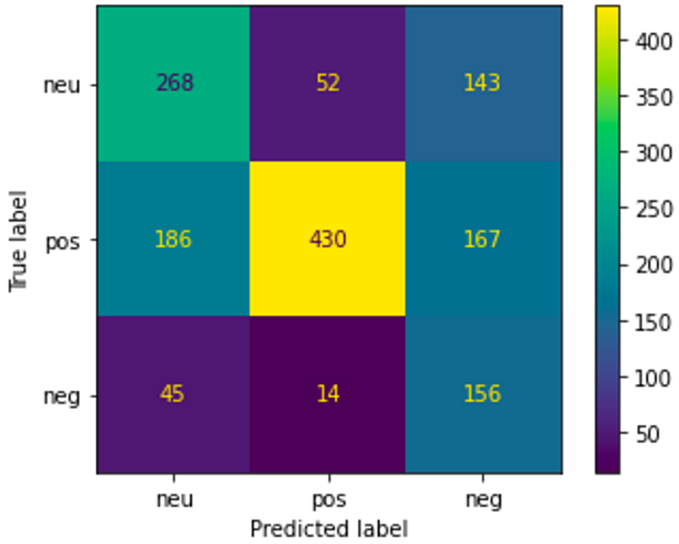
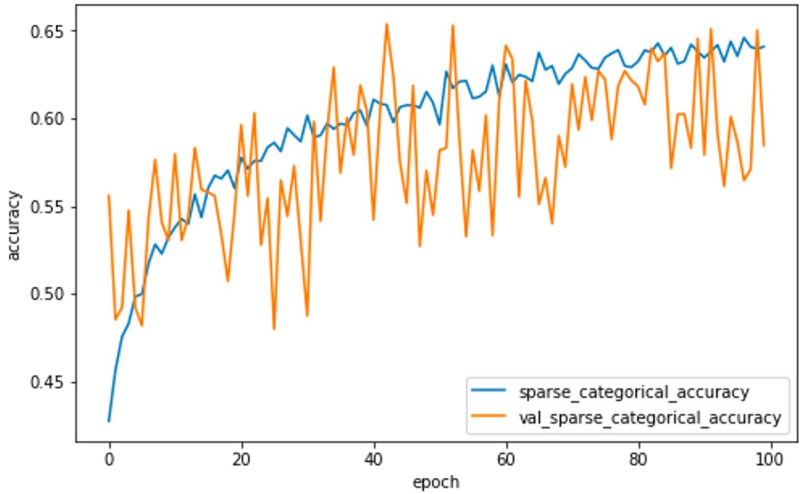
Model Performance

- F1 score: 0.604
- Accuracy: 64.59%





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BERT with Fine Tuning

- 4 dense layers
- 3 dropout layers
  - Prevent overfitting
- Trainable parameters: 108,557,189

Layer (type)	Output Shape	Param #	Connected to
input_ids (InputLayer)	[(None, 100)]	0	[]
token_type_ids (InputLayer)	[(None, 100)]	0	[]
attention_mask (InputLayer)	[(None, 100)]	0	[]
tf_bert_model_1 (TFBertModel)	TFBaseModelOutputWithPoolingAndCrossAttentions(last_hidden_state=(None, 100, 768), pooler_output=(None, 768), past_key_values=None, hidden_states=None, attentions=None, cross_attentions=None)	108310272	['input_ids[0][0]', 'token_type_ids[0][0]', 'attention_mask[0][0]']
dense_4 (Dense)	(None, 256)	196864	['tf_bert_model_1[0][1]']
dropout_77 (Dropout)	(None, 256)	0	['dense_4[0][0]']
dense_5 (Dense)	(None, 128)	32896	['dropout_77[0][0]']
dropout_78 (Dropout)	(None, 128)	0	['dense_5[0][0]']
dense_6 (Dense)	(None, 128)	16512	['dropout_78[0][0]']
dropout_79 (Dropout)	(None, 128)	0	['dense_6[0][0]']
dense_7 (Dense)	(None, 5)	645	['dropout_79[0][0]']

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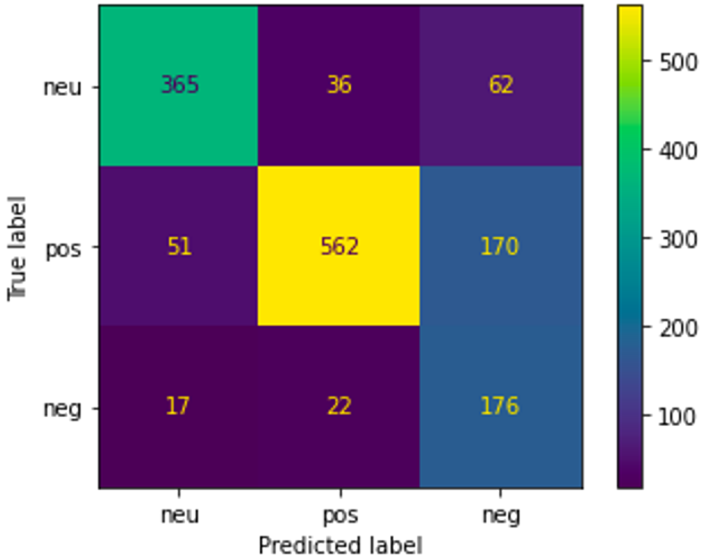
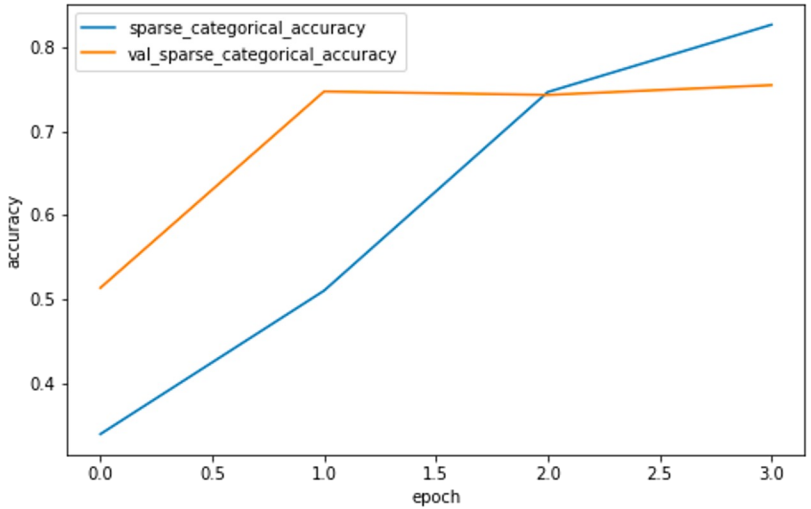
Model Performance

- F1 score: 0.771
- Accuracy: 75.50%





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BERT Transfer Learning

Prep: Fine-tune BERT with Sentiment140

Layer (type)	Output Shape	Param #	Connected to
input_ids (InputLayer)	[(None, 100)]	0	[]
token_type_ids (InputLayer)	[(None, 100)]	0	[]
attention_mask (InputLayer)	[(None, 100)]	0	[]
bert (TFBertMainLayer)	TFBaseModelOutputWithPoolingAndCrossAttentions(last_hidden_state=(None, 100, 768), pooler_output=(None, 768), past_key_values=None, hidden_states=None, attentions=None, cross_attentions=None)	108310272	['input_ids[0][0]', 'token_type_ids[0][0]', 'attention_mask[0][0]']
dense (Dense)	(None, 4)	3076	['bert[0][1]']

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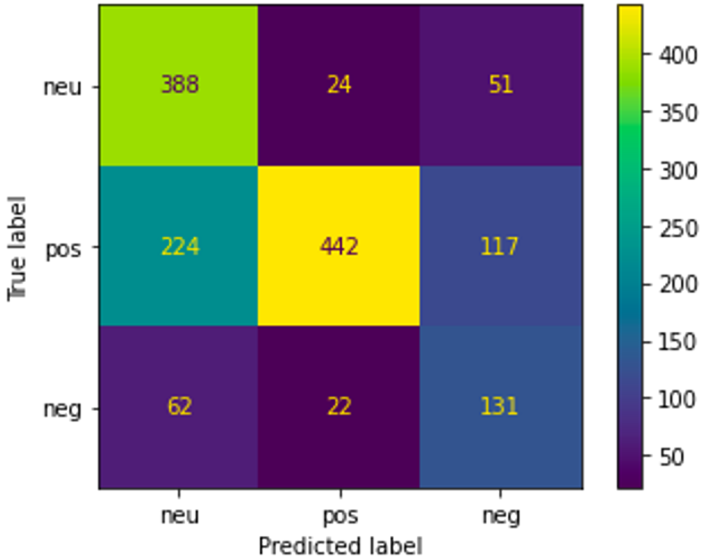
Pre-tuned BERT without Fine Tuning

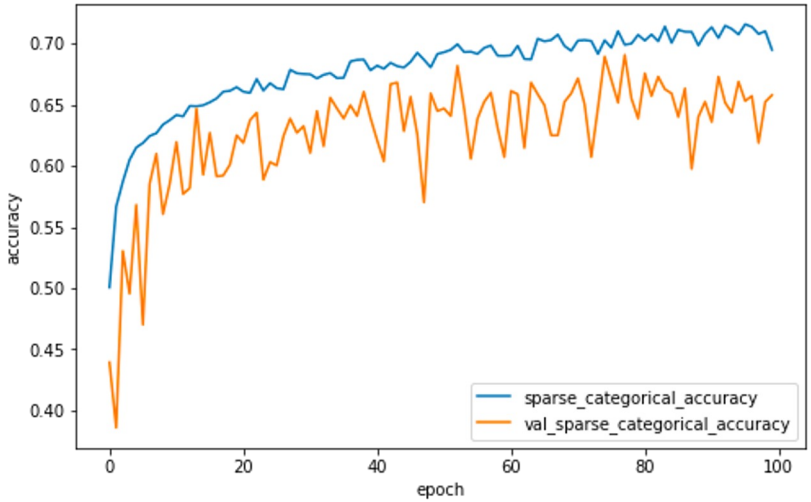
- 4 dense layers
- No dropout layers
- Sentiment140-pretrained BERT layer
- Trainable parameters: 246,917

Layer (type)	Output Shape	Param #	Connected to
input_ids (InputLayer)	[(None, 100)]	0	[]
token_type_ids (InputLayer)	[(None, 100)]	0	[]
attention_mask (InputLayer)	[(None, 100)]	0	[]
bert (Custom>TFBertMainLayer)	{'pooler_output': (None, 768), 'last_hidden_state ': (None, 100, 768) }	108310272	['input_ids[0][0]', 'token_type_ids[0][0]', 'attention_mask[0][0]']
dense (Dense)	(None, 256)	196864	['bert[0][1]']
dense_1 (Dense)	(None, 128)	32896	['dense[0][0]']
dense_2 (Dense)	(None, 128)	16512	['dense_1[0][0]']
dense_3 (Dense)	(None, 5)	645	['dense_2[0][0]']

Model Performance

- F1 score: 0.664
- Accuracy: 69.06%





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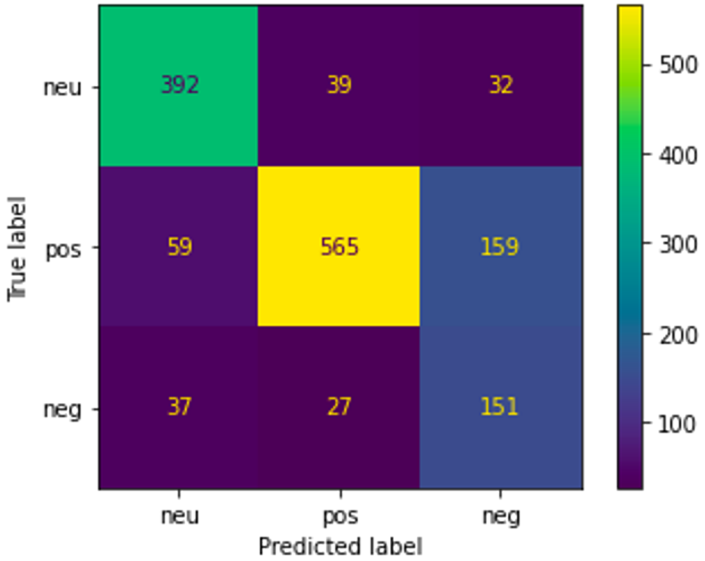
Pre-tuned BERT with Fine Tuning

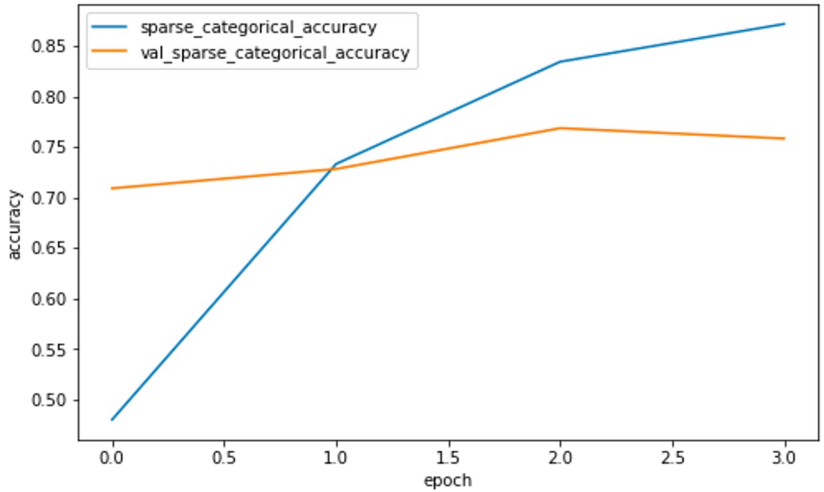
- 4 dense layers
- 3 dropout layer
- Unfreezed Sentiment140-pretrained BERT layer
- Trainable parameters: 108,557,189

Layer (type)	Output Shape	Param #	Connected to
input_ids (InputLayer)	[(None, 100)]	0	[]
token_type_ids (InputLayer)	[(None, 100)]	0	[]
attention_mask (InputLayer)	[(None, 100)]	0	[]
bert (Custom>TFBertMainLayer)	{'last_hidden_state': (None, 100, 768), 'pooler_output': (None, 768)}	108310272	['input_ids[0][0]', 'token_type_ids[0][0]', 'attention_mask[0][0]']
dense (Dense)	(None, 256)	196864	['bert[0][1]']
dropout (Dropout)	(None, 256)	0	['dense[0][0]']
dense_1 (Dense)	(None, 128)	32896	['dropout[0][0]']
dropout_1 (Dropout)	(None, 128)	0	['dense_1[0][0]']
dense_2 (Dense)	(None, 128)	16512	['dropout_1[0][0]']
dropout_2 (Dropout)	(None, 128)	0	['dense_2[0][0]']
dense_3 (Dense)	(None, 5)	645	['dropout_2[0][0]']

Model Performance

- F1 score: 0.775
- Accuracy: 76.52%





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Model Comparison

Dataset	Training Size	Model	Fine Tune	Hidden Dense	Dropout	#Parameters	#Epochs	Best Accuracy	F1 Score
FinTweets	7512	BOW	N/A	(128, 32, 8)	0.75	772,565	15	67.84%	0.681
FinTweets	7041	BERT	N	(256,128,128)	N/A	246,917	100	64.59%	0.643
FinTweets	7041	BERT	Y	(256,128,128)	0.5	108,557,189	4	75.50%	0.771
Sentiment140	120,000	BERT	Y	None	N/A	108,313,348	1	Pre-tuned BERT	
FinTweets	7041	Pre-tuned BERT	N	(256,128,128)	N/A	246,917	100	69.06%	0.664
FinTweets	7041	Pre-tuned BERT	Y	(256,128,128)	0.5	108,557,189	4	76.52%	0.775

Evaluation with GME and Reddit Data

- Data
  - Time frame: 2021/1/1 - 2022/8/31
  - 94,298 GME-related Reddit Submissions from r/GME, r/wallstreetbets
  - GME historical daily price
- Predictions

Sentiment	Count
Positive	61,656
Neutral	18,765
Negative	13.877

Co-movement with Stock Price

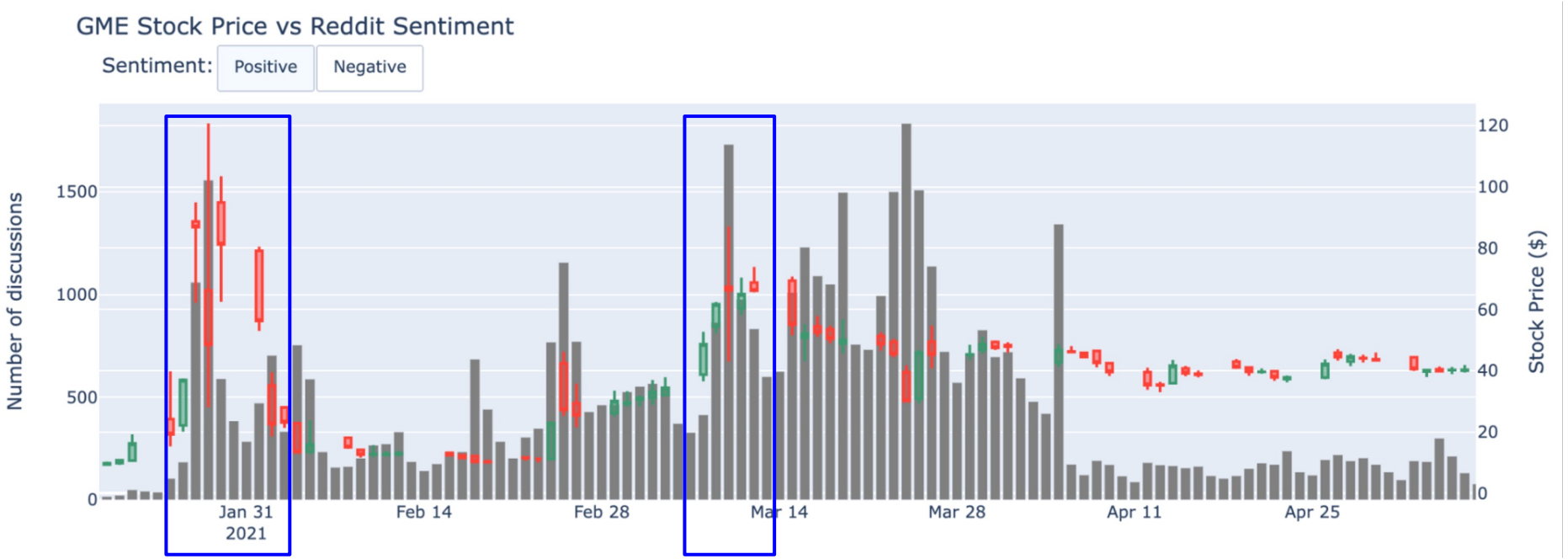

Fig: GME Stock Price vs. Reddit Sentiment

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Co-movement with Stock Price

Fig: GME Stock Price vs. Reddit Sentiment

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Correlation Analysis

- Direct correlation

	Open	High	Low	Close	Return
neg_count	0.190421	0.295703	0.034448	0.135550	-0.088591
pos_count	0.208103	0.294619	0.077112	0.167200	-0.049275
%neg	-0.072633	-0.063947	-0.111795	-0.103508	-0.081021
%pos	0.132717	0.102020	0.183161	0.154084	0.012134

- Correlation with smoothed price (3-day average)

	Open_avg	High_avg	Low_avg	Close_avg	Return_avg
neg_count	0.164997	0.243624	0.035612	0.128597	-0.003135
pos_count	0.187143	0.258480	0.072598	0.157566	0.013169
%neg	-0.064149	-0.058372	-0.099738	-0.091140	-0.101963
%pos	0.143393	0.117465	0.186976	0.160782	-0.001114

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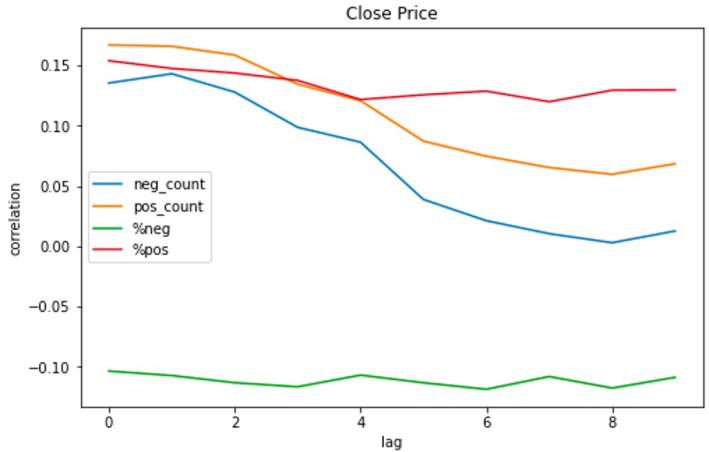
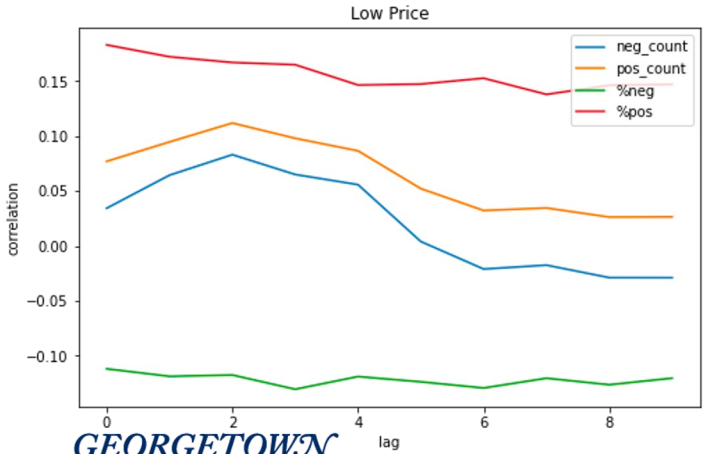
Delayed Time Effect - Time Lagged Cross Correlation

- Lag stock price by 3 days

	Open	High	Low	Close	Return
neg_count	0.112454	0.183123	0.002548	0.069588	-0.071774
pos_count	0.143459	0.206967	0.044253	0.110450	-0.038988
%neg	-0.053496	-0.039359	-0.094069	-0.077686	-0.067056
%pos	0.166088	0.137713	0.203534	0.178016	0.005419

- Time Lagged Cross Correlation





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Stock Price Movement Prediction

- Sentiment: positive counts
- 6 Technical indicators:
  - MOM (Momentum)
  - RSI (Relative Strength Index),
  - NATR (Normalized Average True Range)
  - CCI (Commodity Channel Index)
  - OBV (On Balance Volume)
  - ADX (Average Directional Movement Index)
- Model Architecture: LSTM
  - Data are transformed into blocks with a time step of 14 days
  - 20 epochs
- Performance
  - Best Accuracy:
    - Train: 69.83%
    - Test: 55.74%

Layer (type)	Output Shape	Param #
lstm_30 (LSTM)	(None, 14, 8)	512
dropout_30 (Dropout)	(None, 14, 8)	0
batch_normalization_30 (BatchNormalization)	(None, 14, 8)	32
lstm_31 (LSTM)	(None, 14, 16)	1600
dropout_31 (Dropout)	(None, 14, 16)	0
batch_normalization_31 (BatchNormalization)	(None, 14, 16)	64
lstm_32 (LSTM)	(None, 8)	800
dropout_32 (Dropout)	(None, 8)	0
batch_normalization_32 (BatchNormalization)	(None, 8)	32
dense_10 (Dense)	(None, 1)	9

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Conclusion

- Effect of fine tuning
  - Models with unfreezed parameters and fine tuned in the training process yield significant increases in accuracy.
- Effect of pre-training on Sentiment140
  - Pre-tuning on the Sentiment140 Dataset remains beneficial.
  - Especially effective when the training data size is small.
- Predictive power for stock price
  - Limited availability of data
  - Slightly better than random guess
- Possible further study
  - A decaying learning rate for lower layers, which intuitively would contain more general information.

Code links

Please follow click on Github to view the code

Thanks for watching!

Any questions?

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