Options Prediction with Advanced DL

Project by-
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Understanding Options Pricing

Lets watch a video first!

- Options are financial derivatives that gives the right to buy (call) or sell (put) a security at or before a certain date.
- We use deep learning to construct models that try to price.
- Options using historical data.

5 Basic Characteristics of Every Option

- Underlying asset
- Call vs. put
- Strike price
- Expiration date
- American vs. European

Why？

- The value of a European option can be modeled with the commonly-used

Black-Scholes Model (BS-Model):

$$C = N(d_1)S_t - N(d_2)Ke^{-rt}$$

$$\text{where } d_1 = \frac{\ln\frac{S_t}{K} + (r + \frac{\sigma^2}{2})t}{\sigma\sqrt{t}}$$

$$\text{and } d_2 = d_1 - \sigma\sqrt{t}$$

C = call option price
N = CDF of the normal distribution
S_t = spot price of an asset
K = strike price
r = risk-free interest rate
t = time to maturity
σ = volatility of the asset

This model makes many assumptions (especially of volatility) and often mismatches empirical findings in different options.

How?

We used LSTM(model1) and MLP(model2,model3) architectures to predict the options prices and got results that outperform the Black-Scholes model significantly.

1. Data
2. Models
3. Results

Dataset

- Stock data from yahoo finance

  https://finance.yahoo.com/

- Option data from yahoo finance option

  https://finance.yahoo.com/quote/WIMI/options?p=WIMI

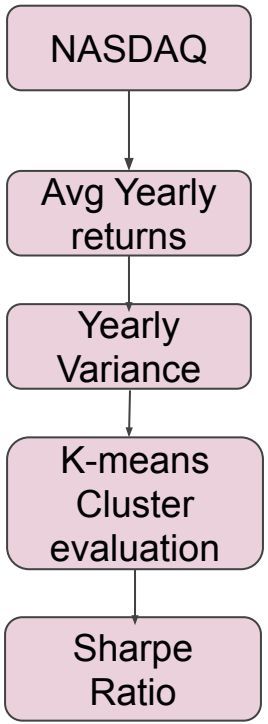
- Treasury Rate

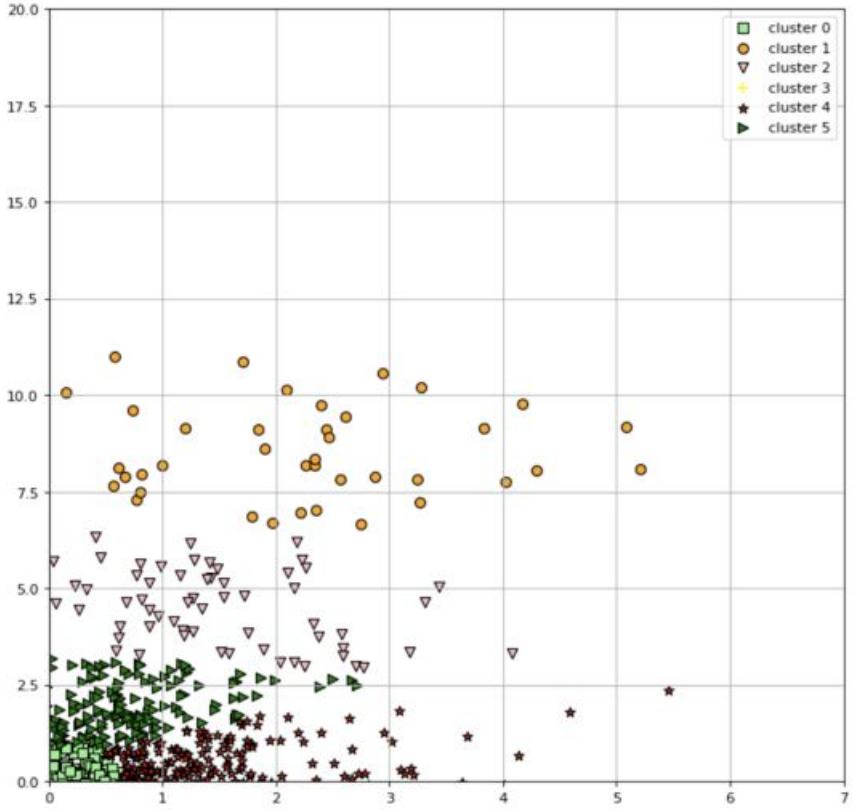
  https://home.treasury.gov/

Stock Picking

How to choose the best stocks?

Strategy





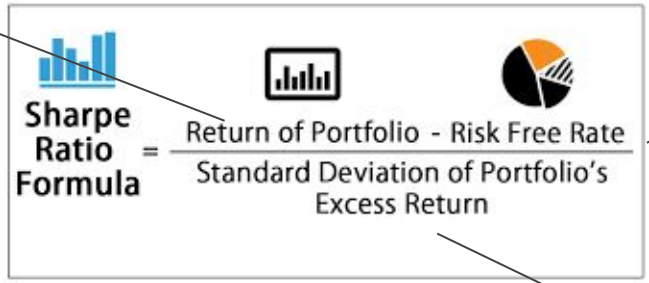
Applying K-means Clustering

Cluster ‘0’ further reduced down to 6 clusters-

	cluster	avg_yearly_returns	yearly_variance	Name
0	3	-0.380375	0.096733	208
1	0	-0.007581	0.063594	984
2	5	0.105799	0.408778	204
3	2	0.284402	0.842208	75
4	4	0.359156	0.130867	246
5	1	0.560519	1.522883	40

Sharpe Ratio for evaluating the best Stocks Cluster

Avg yearly returns



3-years daily U.S. yield rates (https://home.treasury.gov/)

Yearly variance

	cluster	avg_yearly_returns	yearly_variance	sharpe_ratio	Name
0	0	0.289101	0.067665	1.677841	137
1	1	0.326611	0.224425	0.649311	80
2	2	0.779880	0.171351	2.216106	29

Highest Sharpe Ratio

	Name	avg_yearly_returns	yearly_variance	cluster	avg_risk_free_rate	std_dev	sharpe_ratio
1105	NSTG	0.841255	0.022083	2	0.021367	0.148602	5.517324
1646	VCYT	1.015007	0.057058	2	0.021367	0.238869	4.159773
890	JYNT	0.728127	0.037189	2	0.021367	0.192844	3.664930
640	FRPT	0.921197	0.069974	2	0.021367	0.264525	3.401683
1335	RGEN	0.714409	0.058437	2	0.021367	0.241738	2.866914
1474	SPSC	0.604935	0.046052	2	0.021367	0.214596	2.719375
968	LULU	0.674161	0.057792	2	0.021367	0.240400	2.715447
606	FIVN	0.815347	0.103550	2	0.021367	0.321792	2.467373
81	AMD	1.044455	0.189414	2	0.021367	0.435217	2.350752
484	DXCM	0.794039	0.108452	2	0.021367	0.329321	2.346259

How to get options data for free?

```
from bs4 import BeautifulSoup
import requests
import pandas as pd
from datetime import datetime
import time
```

```
def main():
  print("Hello World!")
  if __name__ == '__main__':
    main()
```

```
data_url = "https://finance.yahoo.com/quote/SPY/options"
data_html = requests.get(data_url).content
print(data_html)
```

https://www.freecodecamp.org/news/how-i-get-options-data-for-free-fba22d395cc8/

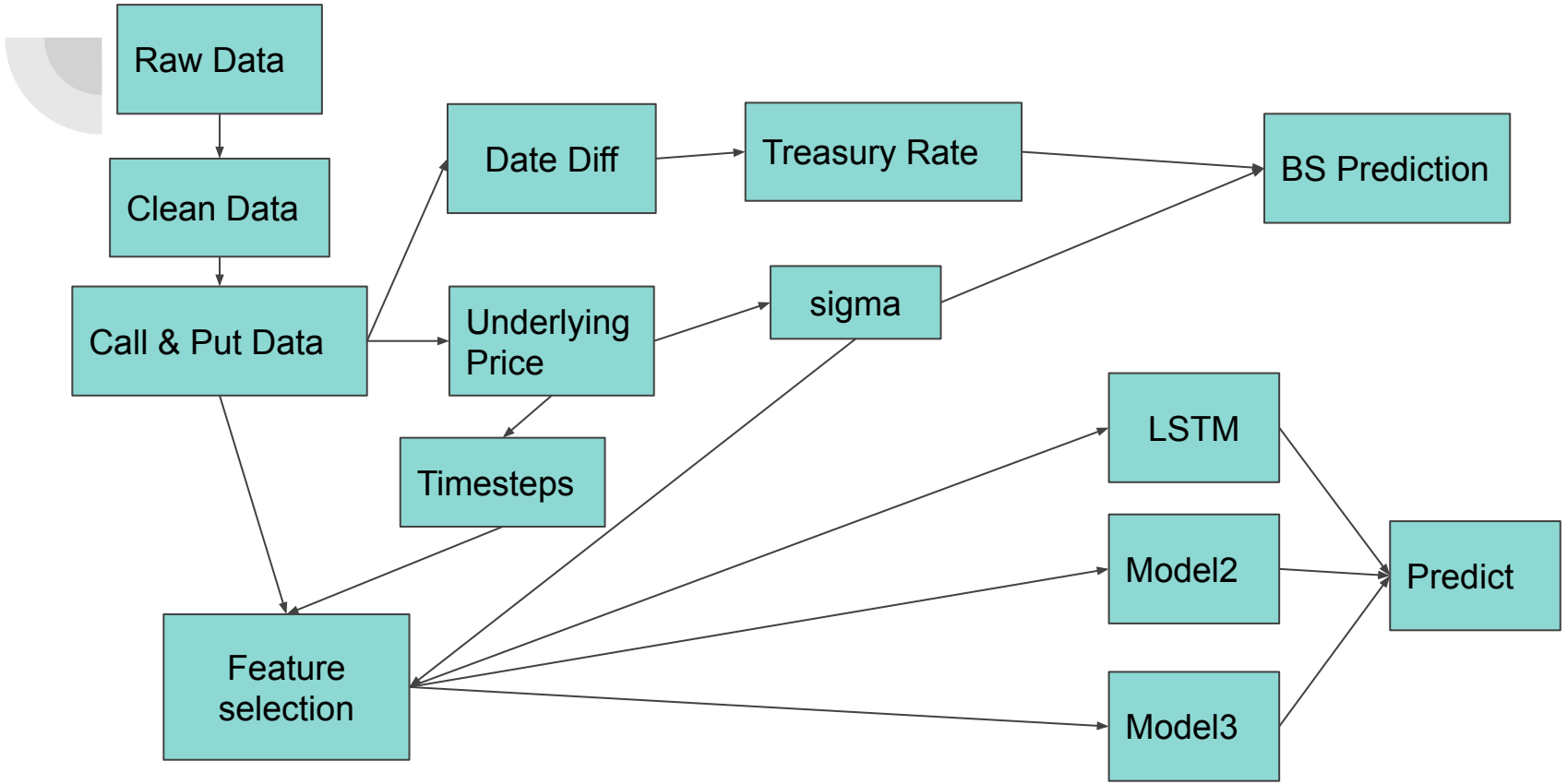
Definitions

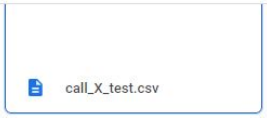
```
df.head()
```

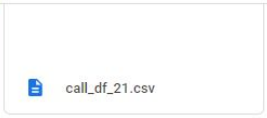
UnderlyingSymbol	UnderlyingPrice	Exchange	OptionSymbol	Blank	Type	Expiration	DataDate	Strike	Last	Bid	Ask	Volume	OpenInterest
ADSK	107.12	W	ADSK180105C00060000	NaN	call	01/05/2018	1/2/2018 04:00:00 PM	60.0	0.0	44.85	49.50	0.0	0.0

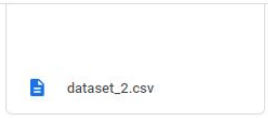
* Underlying:The stock, index, or ETF symbol
* Underlying_price: The last traded price at the time of the option quote.
* Option type: Call or put Expiration The expiration date of the option.
* Expiration date: The date of the expiration
* Strike: The strike of the option
* Bid: The bid price of the option
* Ask: The ask price of the option
* Volume: The number of contracts traded
* Open interest : always a day behind. The OCC changes this number at 3:00AM every morning and the number does not change through the day

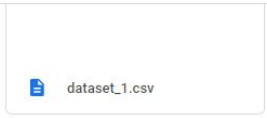
Data Preprocessing

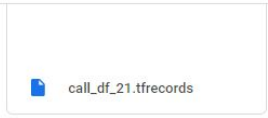


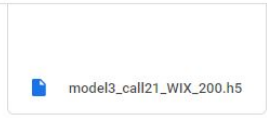

call_X_test.csv


call_df_21.csv

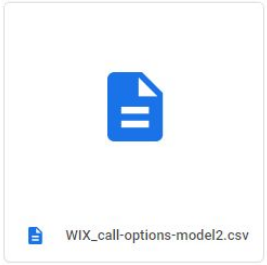

dataset_2.csv

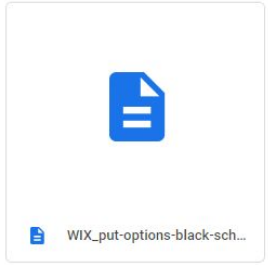

dataset_1.csv

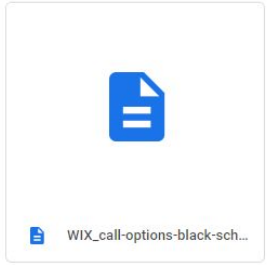

call_df_21.tfrecords


model3_call21_WIX_200.h5

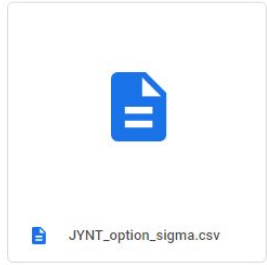

model2_call21_WIX.h5


WIX_call-options-model2.csv


WIX_put-options-black-sch...


WIX_call-options-black-sch...


WIX_option_treasury.csv


JYNT_option_sigma.csv


BLFS_option_sigma.csv

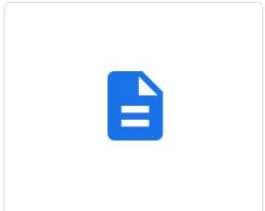

WIX_option_sigma.csv

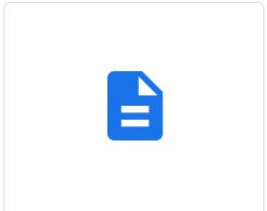

VICR_option_sigma.csv

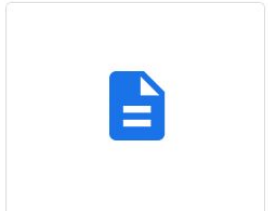

VCYT_option_sigma.csv

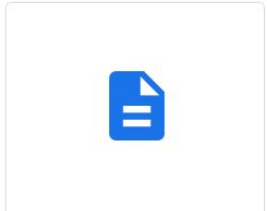

STAA_option_sigma.csv

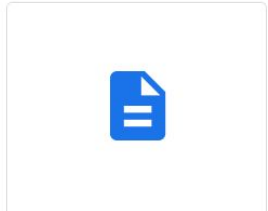

SPSC_option_sigma.csv

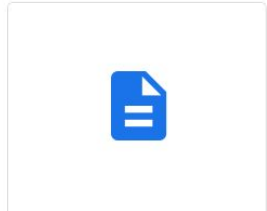






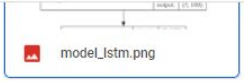






CMPE297_49_project > models

Talking: Jacky Chow



model_lstm.png

model1_lstm_call_1.h5

model1_lstm_call_2.h5

model1_lstm_put_1.h5

model2_call_sigma5_all_4...

model2_call5_all_best.h5

model2_call10_all_best.h5

model2_call21_all_400.h5

model2_call21_all_600.h5

model2_call21_all_1200.h5

model2_call21_all_2400.h5

model2_call21_all_4000.h5

model2_call21_all_best.h5

model2_call21_WIX.h5

model2_call21_WIX.h5

model2_put_all_300.h5

model2_put_all_1500.h5

model2_put_all_2400.h5

model2_put21_all_best.h5

model2_put21_all5_best.h5

model3_call_all_300.h5

model3_call_all_800.h5

model3_call_all_1024_400...

model3_call_all_1024_600...

model3_call_all_2000.h5

model3_call_sigma5_all_1...

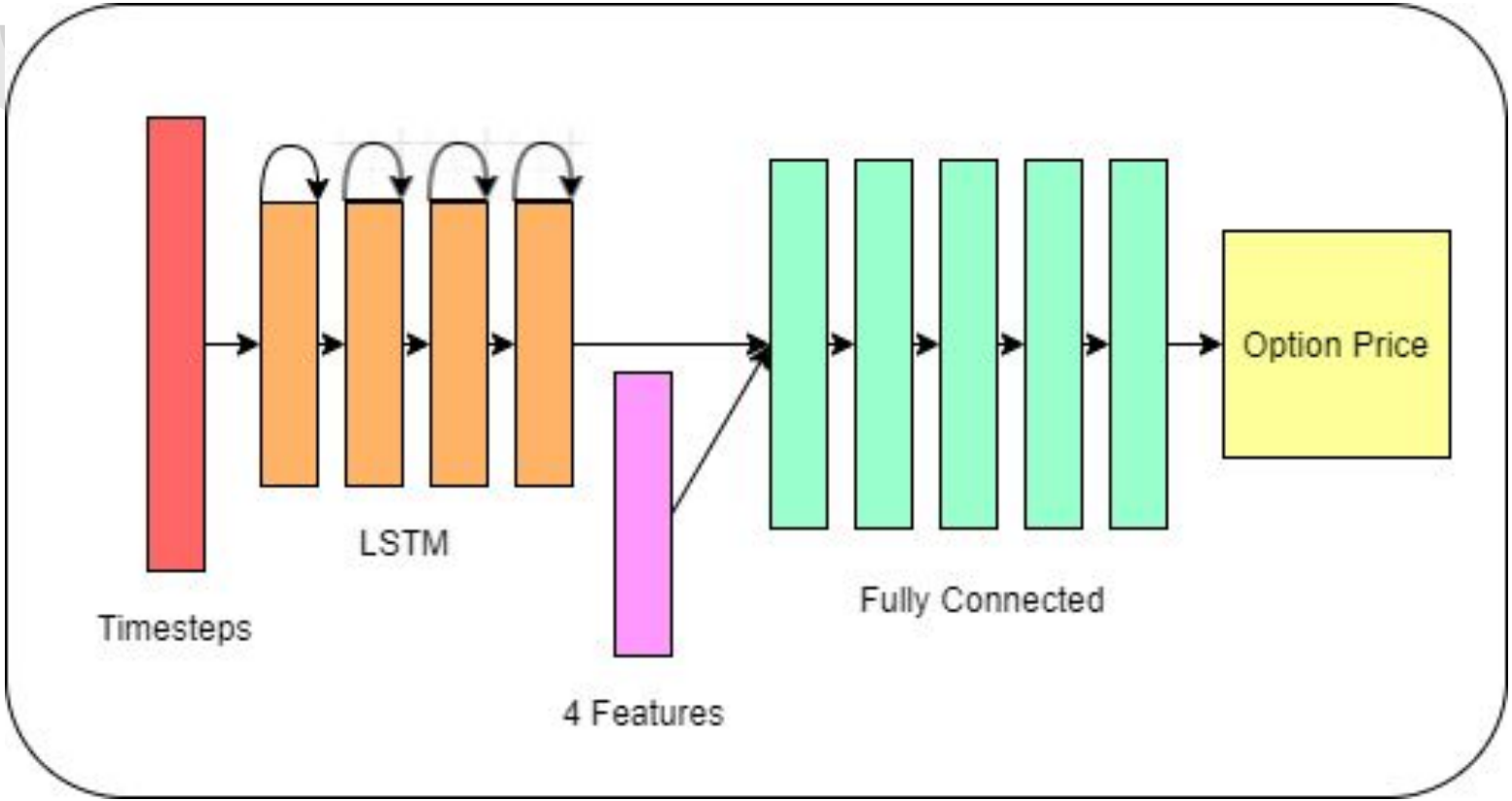
model3_call5_all_best.h5

model3_call21_all_best.h5

LSTM Features Timestep 5

	UnderlyingPrice	Strike	Bid	Ask	date_diff	treasury_rate	1	2	3	4	5
2344	11.91	0.5	11.35	11.45	3	1.33	11.91	12.02	12.1404	11.96	11.82
2345	11.91	1.0	10.90	10.95	3	1.33	11.91	12.02	12.1404	11.96	11.82
2346	11.91	1.5	10.35	10.45	3	1.33	11.91	12.02	12.1404	11.96	11.82
2347	11.91	2.0	9.90	9.95	3	1.33	11.91	12.02	12.1404	11.96	11.82
2348	11.91	2.5	9.35	9.45	3	1.33	11.91	12.02	12.1404	11.96	11.82
...	...	...	...	...	...	...	...	...	...	...	...
702371	148.52	185.0	16.40	19.20	534	2.00	30.45	33.87	33.4800	34.02	33.67
702372	148.52	190.0	15.00	17.80	534	2.00	30.45	33.87	33.4800	34.02	33.67
702373	148.52	195.0	13.90	16.40	534	2.00	30.45	33.87	33.4800	34.02	33.67
702374	148.52	200.0	12.90	15.20	534	2.00	30.45	33.87	33.4800	34.02	33.67
702375	148.52	210.0	10.10	13.20	534	2.00	30.45	33.87	33.4800	34.02	33.67

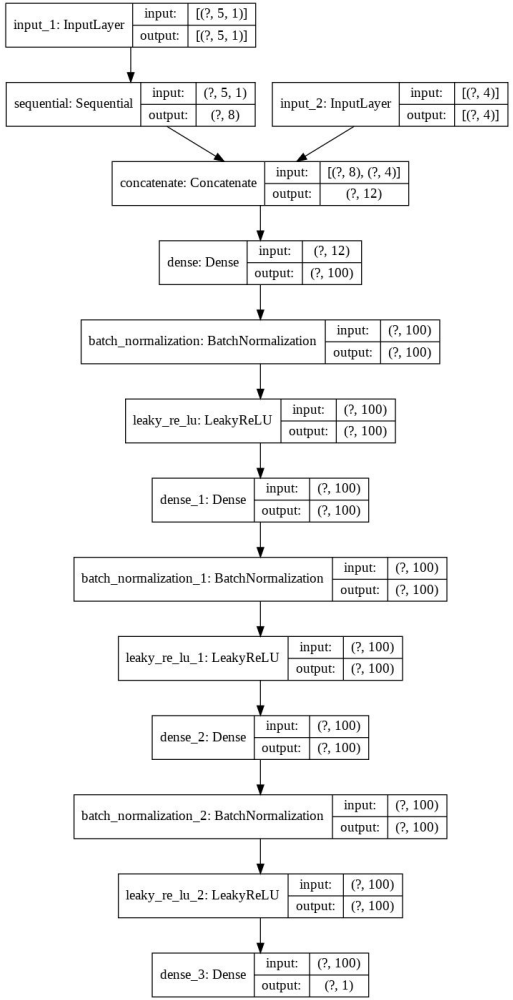
LSTM



Models- LSTM

```
call_model.summary()
```

```
Model: "functional_1"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 5, 1)]       0
__________________________________________________________________________________________________
sequential (Sequential)         (None, 8)            1952        input_1[0][0]
__________________________________________________________________________________________________
input_2 (InputLayer)            [(None, 4)]          0
__________________________________________________________________________________________________
concatenate (Concatenate)       (None, 12)           0           sequential[0][0]
                                                                 input_2[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 100)          1300        concatenate[0][0]
__________________________________________________________________________________________________
batch_normalization (BatchNorma (None, 100)          400         dense[0][0]
__________________________________________________________________________________________________
leaky_re_lu (LeakyReLU)         (None, 100)          0           batch_normalization[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 100)          10100       leaky_re_lu[0][0]
__________________________________________________________________________________________________
batch_normalization_1 (BatchNor (None, 100)          400         dense_1[0][0]
__________________________________________________________________________________________________
leaky_re_lu_1 (LeakyReLU)       (None, 100)          0           batch_normalization_1[0][0]
__________________________________________________________________________________________________
dense_2 (Dense)                 (None, 100)          10100       leaky_re_lu_1[0][0]
__________________________________________________________________________________________________
batch_normalization_2 (BatchNor (None, 100)          400         dense_2[0][0]
__________________________________________________________________________________________________
leaky_re_lu_2 (LeakyReLU)       (None, 100)          0           batch_normalization_2[0][0]
__________________________________________________________________________________________________
dense_3 (Dense)                 (None, 1)            101         leaky_re_lu_2[0][0]
==================================================================================================
Total params: 24,753
```



Model2/Model3 Features Sigma 5

```
call_df_5.head()
```

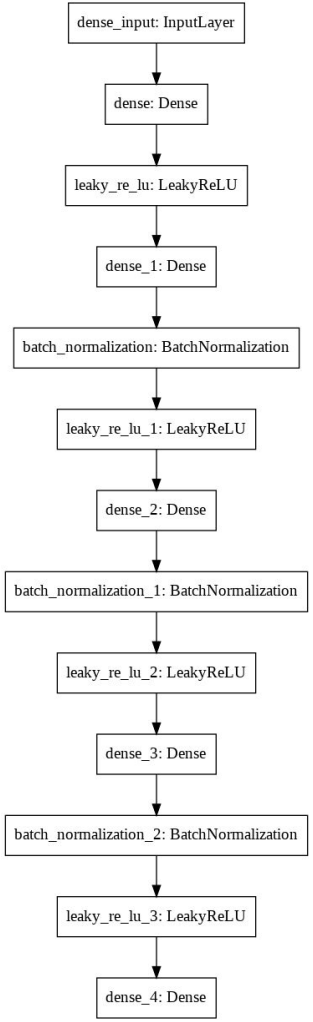
	UnderlyingPrice	Strike	Bid	Ask	sigma_5	date_diff	treasury_rate
1042	12.28	5.5	6.75	6.85	0.033379	4	1.3
1043	12.28	6.0	6.20	6.35	0.033379	4	1.3
1044	12.28	6.5	5.75	5.85	0.033379	4	1.3
1045	12.28	7.0	5.25	5.35	0.033379	4	1.3
1046	12.28	7.5	4.70	4.85	0.033379	4	1.3

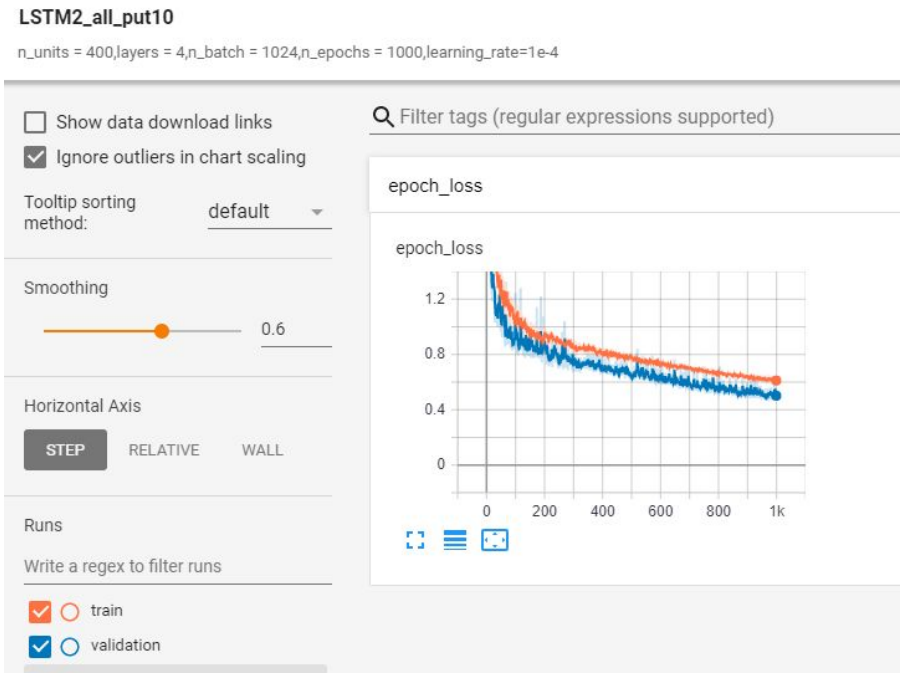
```
for day in [5, 10, 21, 30]:
  df_underlying['sigma_'+str(day)] = df_underlying['UnderlyingPrice'].rolling(day).apply(lambda x: (np.diff(x) / x[:-1]).std())
```

Models- Model2/3

Same architecture as Model2 ,but Model3 predict both ask and bid prices (Two output can be used for options seller).

```
Model: "sequential_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_13 (Dense)             (None, 400)               2400
_________________________________________________________________
leaky_re_lu_8 (LeakyReLU)    (None, 400)               0
_________________________________________________________________
dense_14 (Dense)             (None, 400)               160400
_________________________________________________________________
batch_normalization (BatchNo (None, 400)               1600
_________________________________________________________________
leaky_re_lu_9 (LeakyReLU)    (None, 400)               0
_________________________________________________________________
dense_15 (Dense)             (None, 400)               160400
_________________________________________________________________
batch_normalization_1 (Batch (None, 400)               1600
_________________________________________________________________
leaky_re_lu_10 (LeakyReLU)   (None, 400)               0
_________________________________________________________________
dense_16 (Dense)             (None, 400)               160400
_________________________________________________________________
batch_normalization_2 (Batch (None, 400)               1600
_________________________________________________________________
leaky_re_lu_11 (LeakyReLU)   (None, 400)               0
_________________________________________________________________
dense_17 (Dense)             (None, 2)                 802
=================================================================
Total params: 489,202
Trainable params: 486,802
Non-trainable params: 2,400
_________________________________________________________________
```



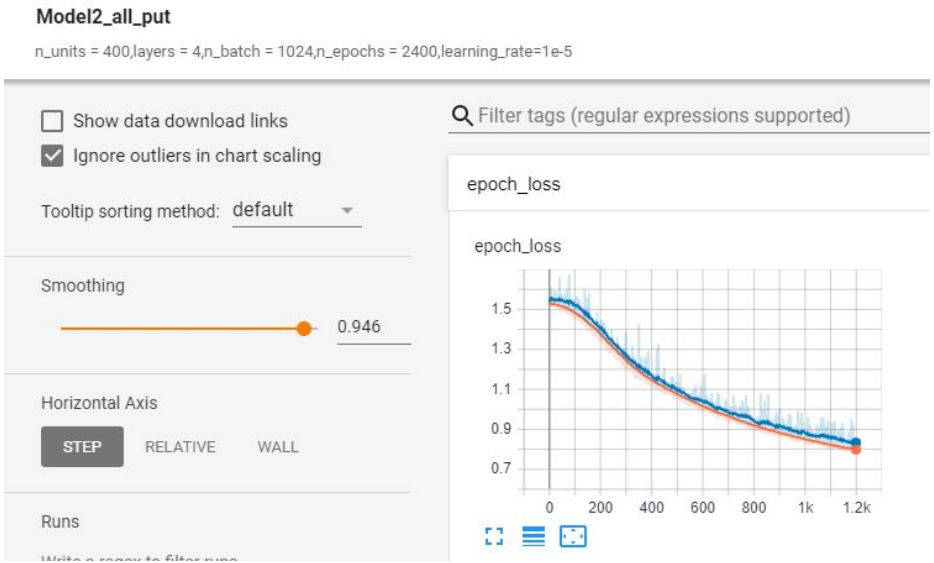


LSTM

Put5
https://tensorboard.dev/experiment/IN9XplUvRbqhaVBvCPIJSg/
Put10
https://tensorboard.dev/experiment/oQljEuYVSvOLPDi17AtRww/#scalars
Put21
https://tensorboard.dev/experiment/h5KIjLjiQPmdk9cvD9JD6A/

Call10
https://tensorboard.dev/experiment/9tG0Hv68TmyaI7NBnbr2Ow/

Call21
https://tensorboard.dev/experiment/ZE4cErmZRXKKvUJRpHbjHQ/#scalars



Model2:

Call 5
https://tensorboard.dev/experiment/Bgx7f38NSgOtJQdNMXI9JA/#scalars
call10
https://tensorboard.dev/experiment/y9MuyU77Tymi0Uz1Yb0NSA/#scalars
Call 21
https://tensorboard.dev/experiment/y9MuyU77Tymi0Uz1Yb0NSA/

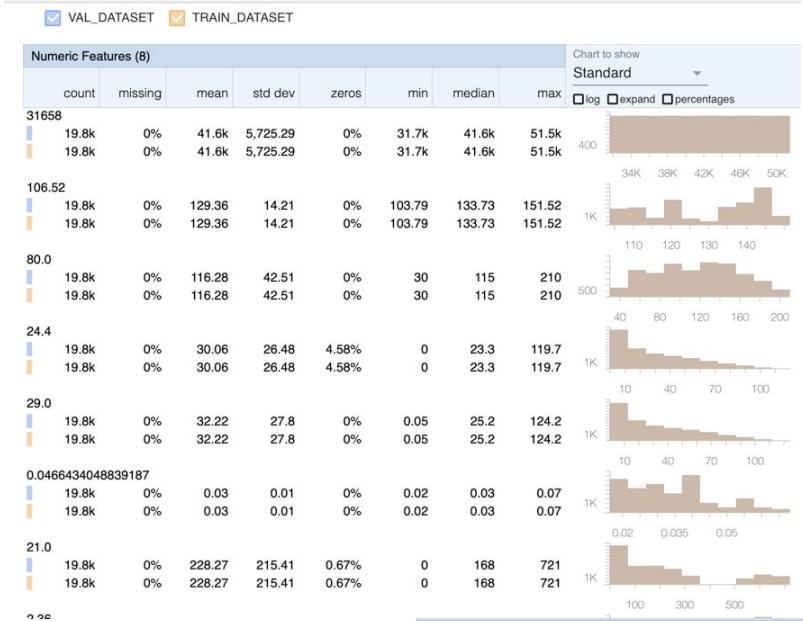
put5
https://tensorboard.dev/experiment/L208zOrlRziyfgiEm9RjjQ/#scalars
Put21
https://tensorboard.dev/experiment/L208zOrlRziyfgiEm9RjjQ/

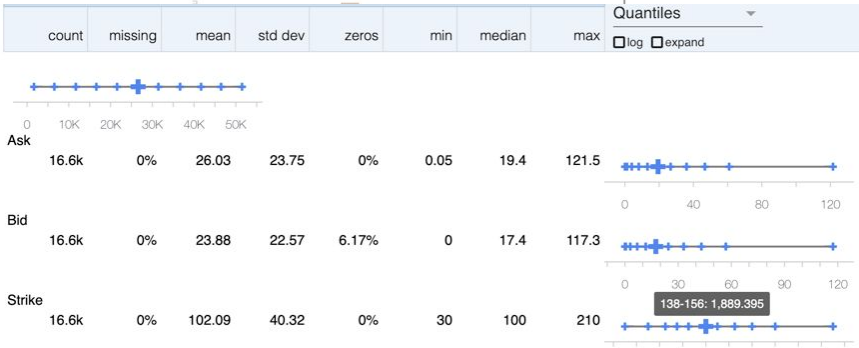
Model3:

call5
https://tensorboard.dev/experiment/X4dEGe3NQbOBOU5vFzHQuw/
Call21
https://tensorboard.dev/experiment/V2WF49BDQIK1spQ21eedfA/

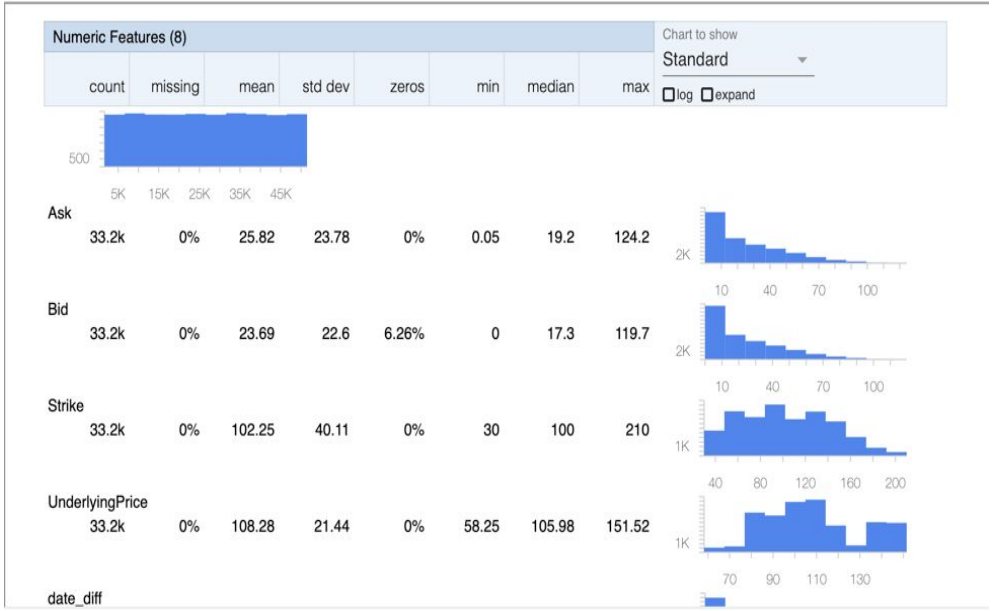
Put5
https://tensorboard.dev/experiment/RY5C4BGKRIKpndYhO4sdqg/
Put21
https://tensorboard.dev/experiment/9zzUE8NcQoySec6DarEo9g/

TFX Data Visualization





Data Schema/Statistics



Feature name	Anomaly short description	Anomaly long description
'treasury_rate'	Column dropped	Column is completely missing
'\'29.0\''	New column	New column (column in data but not in schema)
'\'80.0\''	New column	New column (column in data but not in schema)
'\'24.4\''	New column	New column (column in data but not in schema)
'date_diff'	Column dropped	Column is completely missing
'31658'	New column	New column (column in data but not in schema)
'\'106.52\''	New column	New column (column in data but not in schema)
'Bid'	Column dropped	Column is completely missing
'0.0466434048839187\''	New column	New column (column in data but not in schema)
'Ask'	Column dropped	Column is completely missing
'UnderlyingPrice'	Column dropped	Column is completely missing
'\'21.0\''	New column	New column (column in data but not in schema)
'sigma_21'	Column dropped	Column is completely missing
'Strike'	Column dropped	Column is completely missing
'\'2.36\''	New column	New column (column in data but not in schema)

TFX Model Serving

```
2020-12-07 00:54:58.210420: I external/org_tensorflow/tensorflow/cc/saved_model/loader.cc:199] Restoring SavedModel bundle.
2020-12-07 00:54:58.254873: I external/org_tensorflow/tensorflow/cc/saved_model/loader.cc:183] Running initialization op on SavedModel bundle a
2020-12-07 00:54:58.262050: I external/org_tensorflow/tensorflow/cc/saved_model/loader.cc:303] SavedModel load for tags { serve }; Status: succ
2020-12-07 00:54:58.263058: I tensorflow_serving/servables/tensorflow/saved_model_warmup_util.cc:59] No warmup data file found at /tmp/1/assets
2020-12-07 00:54:58.263216: I tensorflow_serving/core/loader_harness.cc:87] Successfully loaded servable version {name: first_model version: 1}
2020-12-07 00:54:58.264399: I tensorflow_serving/model_servers/server.cc:367] Running gRPC ModelServer at 0.0.0.0:8500 ...
[warn] getaddrinfo: address family for nodename not supported
2020-12-07 00:54:58.265214: I tensorflow_serving/model_servers/server.cc:387] Exporting HTTP/REST API at:localhost:8501 ...
[evhttp_server.cc : 238] NET LOG: Entering the event loop ...
```

Predictions

```
'{"signature_name": "serving_default", "instances": [[141.96, 190.0, 0.040351047419522064, 225.0, 2.22], [82.85, 70.0, 0.02629
471439129068, 37.0, 1.64], [97.4, 155.0, 0.03228772966546013, 571.0, 2.54], [110.11, 135.0, 0.06315234590095266, 42.0, 2.41],
[109.1, 95.0, 0.016403341833589692, 140.0, 2.52], [137.46, 115.0, 0.026066182636784167, 4.0, 2.41], [79.65, 60.0, 0.0264284369
79249875, 228.0, 1.86], [105.2, 130.0, 0.02488153995771937, 178.0, 2.19], [79.35, 75.0, 0.02112959870762864, 318.0, 2.06], [9
7.4, 45.0, 0.03228772966546013, 116.0, 1.93], [111.96, 70.0, 0.04309717861046268, 17.0, 2.14], [106.3, 60.0, 0.036272658671604
59, 15.0, 1.98], [96.6, 135.0, 0.06593577053311157, 63.0, 2.36], [90.65, 145.0, 0.05369590696567412, 744.0, 2.5], [108.15, 95.
0, 0.019538741688308l7, 130.0, 2.46], [101.34, 120.0, 0.05211642321528565, 93.0, 2.45], [89.4, 40.0, 0.029073305894613l3, 93.
0, 1.81], [141.96, 55.0, 0.040351047419522064, 225.0, 2.22], [125.75, 65.0, 0.0567472996325723, 696.0, 2.5], [122.65, 170.0,
0.04381723541187575, 191.0, 2.46], [112.0, 75.0, 0.044291377964058416, 480.0, 2.6], [95.0, 60.0, 0.039871988179493965, 535.0,
2.44], [142.03, 190.0, 0.02304807360549109, 256.0, 2.46], [119.3, 60.0, 0.041100395508881706, 108.0, 2.42], [107.6, 145.0, 0.0
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1936, 291.0, 2.08], [144.62, 155.0, 0.02990831354276945, 108.0, 2.2], [112.45, 65.0, 0.046253993306802715, 485.0, 2.58], [148.
12, 105.0, 0.03955871329297976, 28.0, 2.16], [140.94, 80.0, 0.036935548741476684, 590.0, 1.83], [86.45, 110.0, 0.0358836905231
```

MSE Results

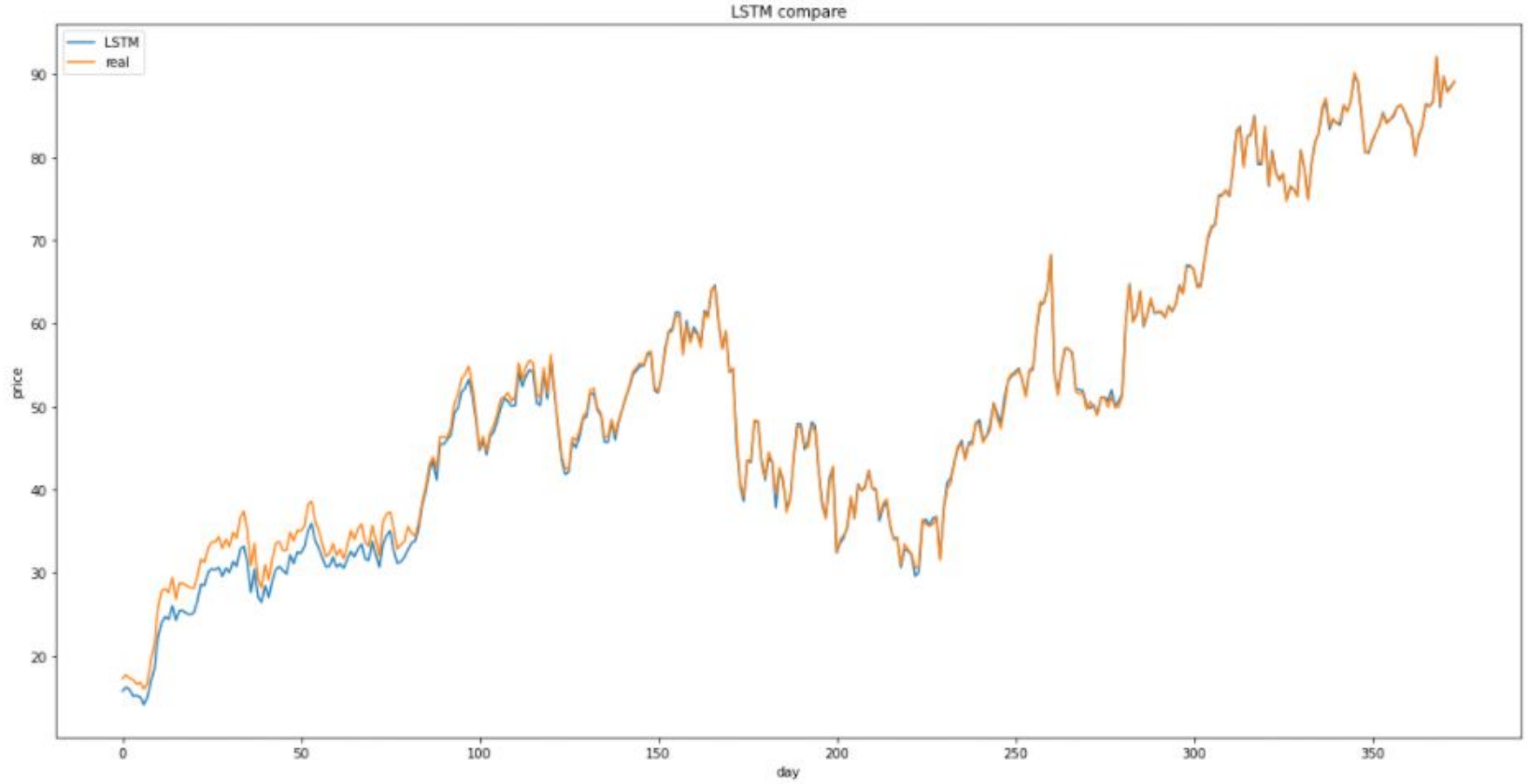
model	learning rate	Batch Size	epoch	sigma	MSE
LSTM call	0.0001	1024	1000	21	0.58
LSTM put	0.0001	1024	1000	10	0.6089
Model2 call	1.00E-05	1024	4000	21	0.8284
Model2 put	1.00E-05	1024	3000	5	0.821
Model3 call	1.00E-05	1024	2000	5	0.4618
Model3 put	1.00E-05	1024	4000	21	0.8204

model	sigma5	sigma10	sigma21
LSTM call	0.8	0.6206	0.58
LSTM put	0.69	0.6089	0.6206
Model2 call	0.833	0.8442	0.8284
Model2 put	0.821	0.9118	0.832
Model3 call	0.4618	0.8623	0.7406
Model3 put	0.8602	1.0232	0.8204
BS Model call	Nan	Nan	23.2528235
Bs Model put	Nan	Nan	23.7103045

model	MSE
LSTM call	0.58
LSTM put	0.6089
Model2 call	0.8284
Model2 put	0.832
Model3 call	0.4618
Model3 put	0.8204
BS Model call	23.2528235
Bs Model put	23.7103045

LSTM Mean Price Prediction

```
<matplotlib.legend.Legend at 0x7f386188ef28>
```



Model2 Mean Price Prediction

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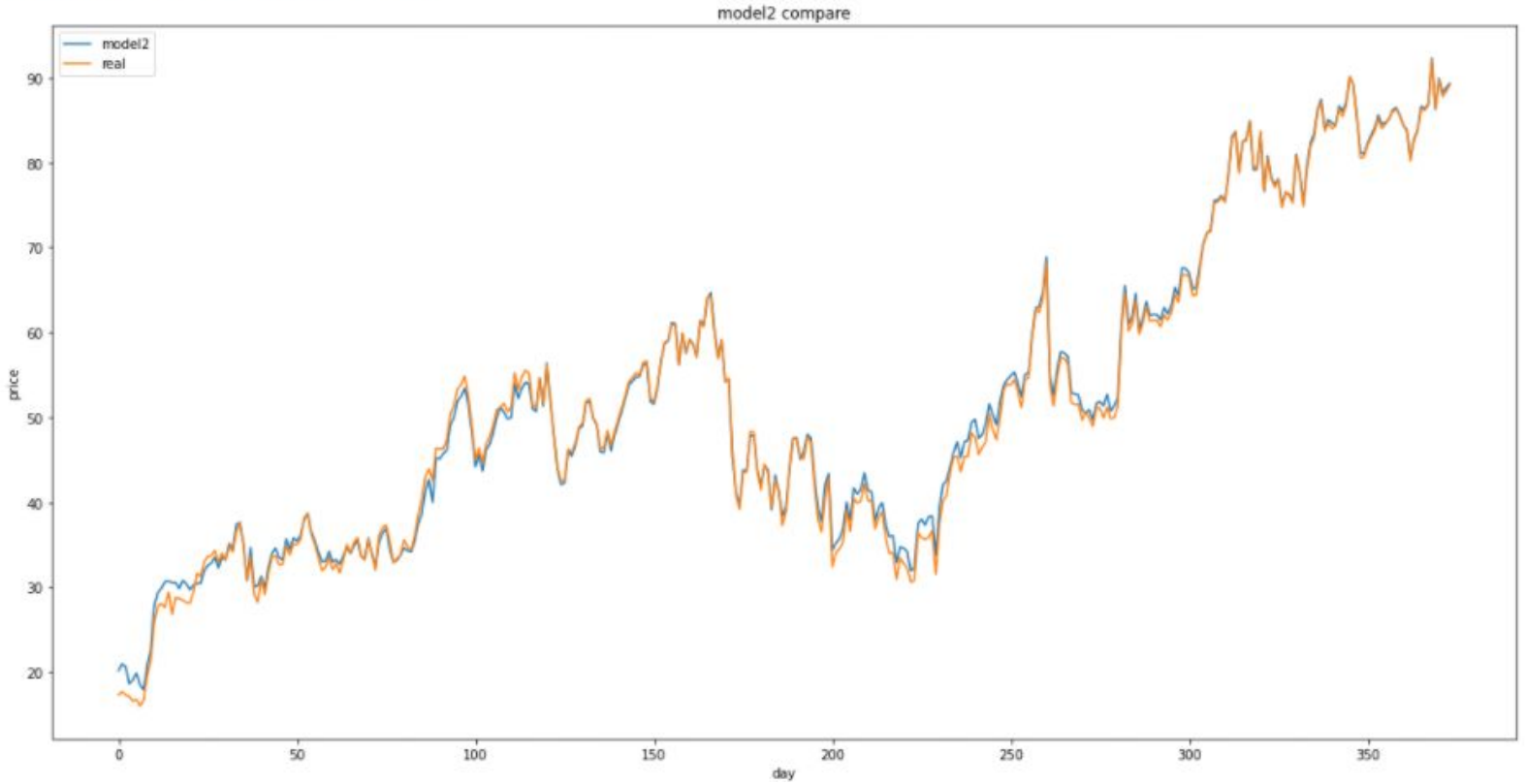
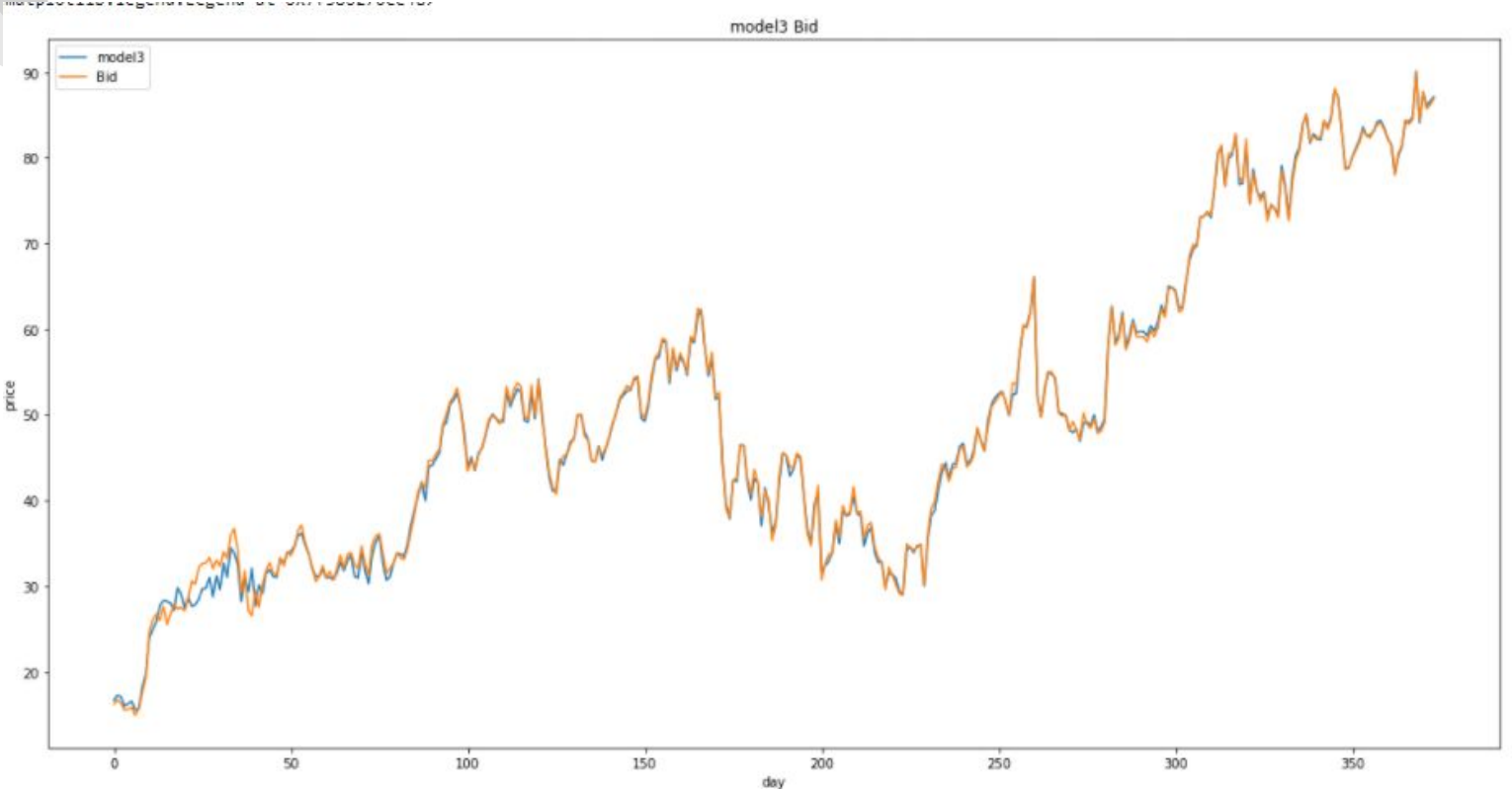
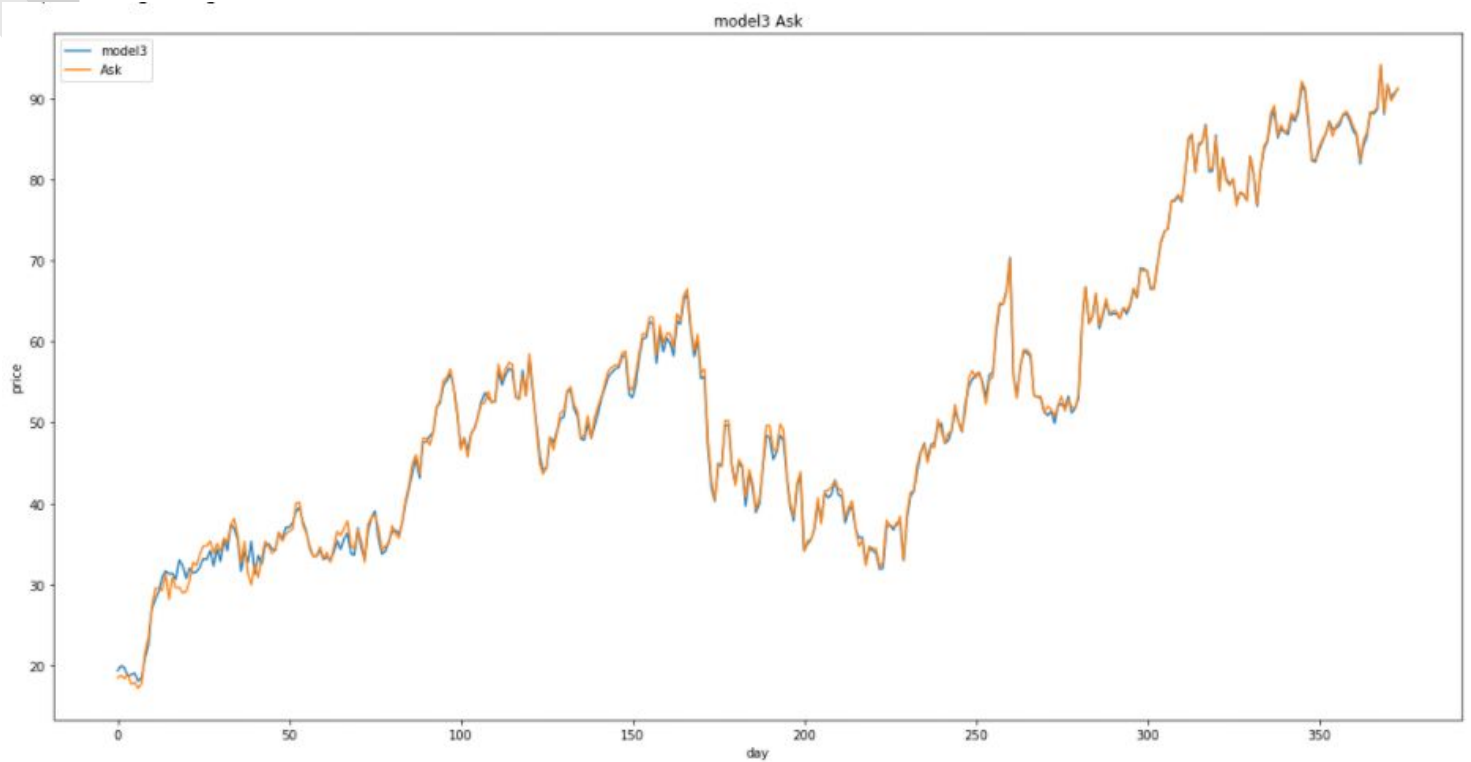
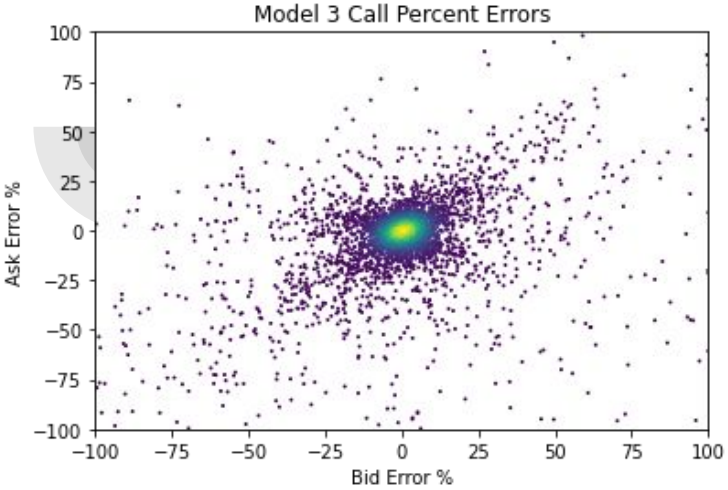


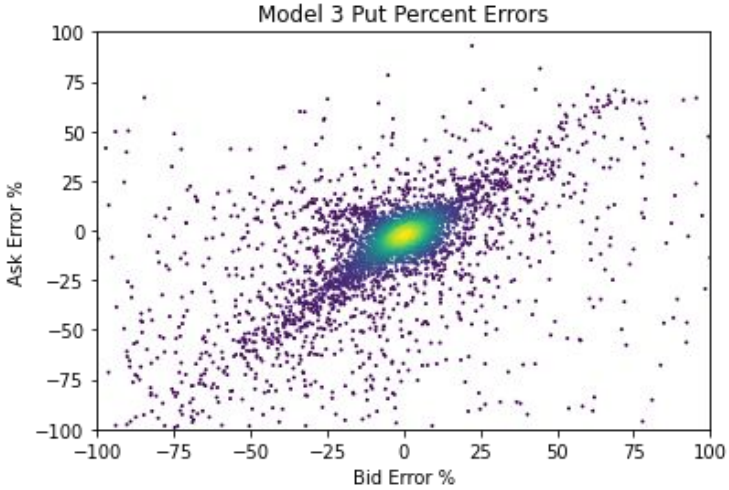
Model 3 Bid price Prediction

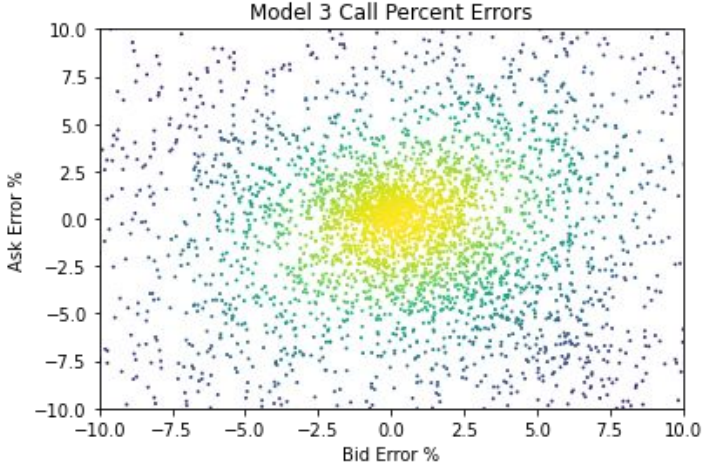


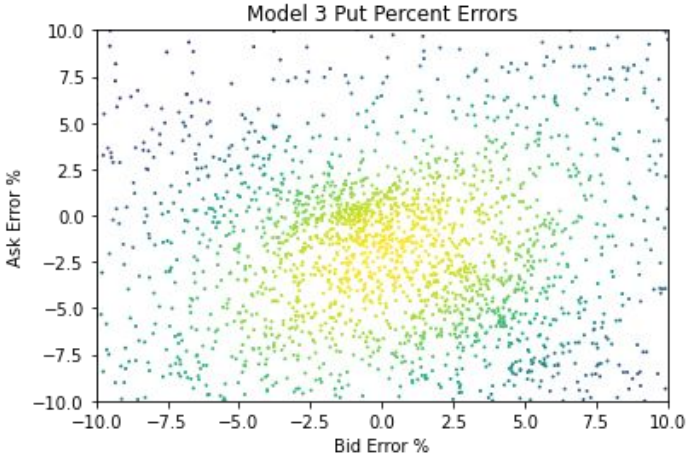
Model 3 on Ask price Prediction




Model 3 Call Percent Errors
Ask Error %
Bid Error %
100
75
50
25
0
−25
−50
−75
−100


Model 3 Put Percent Errors
Ask Error %
Bid Error %
100
75
50
25
0
−25
−50
−75
−100


Model 3 Call Percent Errors
Ask Error %
Bid Error %
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0


Model 3 Put Percent Errors
Ask Error %
Bid Error %
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0

Github:
https://github.com/zjzsu2000/CMPE297_AdvanceDL_Project

Future Work

- **Stocks filter** — Using the stocks with better Sharpe Rate
- **Option filter**
  - Not using the options deep out of the money(The Deep-OTM options are more volatile)
  - Not using the options expired in 7 days (The options closer to the expiry date are more volatile)
- **More models, More data, More training, More metric**
- **Apply to the real trading**
- **Fine-tuning with more hyperparameters**