```
!pip install git+https://github.com/AI4Finance-Foundation/FinRL.git
```

```
Requirement already satisfied: frozenlist>=1.1.1 in /usr/local/lib/python3.7/dist-packages (from aiohttp->ray[default,tune]==1.3.0->f
Requirement already satisfied: charset-normalizer<3.0,>=2.0 in /usr/local/lib/python3.7/dist-packages (from aiohttp->ray[default,tune
Requirement already satisfied: yarl<2.0,>=1.0 in /usr/local/lib/python3.7/dist-packages (from aiohttp->ray[default,tune]==1.3.0->finr
Requirement already satisfied: aiosignal>=1.1.2 in /usr/local/lib/python3.7/dist-packages (from aiohttp->ray[default,tune]==1.3.0->fi
Requirement already satisfied: async-timeout<5.0,>=4.0.0a3 in /usr/local/lib/python3.7/dist-packages (from aiohttp->ray[default,tune]
Requirement already satisfied: attrs>=17.3.0 in /usr/local/lib/python3.7/dist-packages (from aiohttp->ray[default,tune]==1.3.0->finrl
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Requirement already satisfied: multidict<7.0,>=4.5 in /usr/local/lib/python3.7/dist-packages (from aiohttp->ray[default,tune]==1.3.0-
Requirement already satisfied: packaging in /usr/local/lib/python3.7/dist-packages (from deprecation==2.1.0->alpaca_trade_api>=2.1.0-
Requirement already satisfied: certifi>=2018.1.18 in /usr/local/lib/python3.7/dist-packages (from ccxt>=1.66.32->finrl==0.3.5) (2022.
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Requirement already satisfied: cffi>=1.12 in /usr/local/lib/python3.7/dist-packages (from cryptography>=2.6.1->ccxt>=1.66.32->finrl==
Requirement already satisfied: pycparser in /usr/local/lib/python3.7/dist-packages (from cffi>=1.12->cryptography>=2.6.1->ccxt>=1.66.
Requirement already satisfied: pandas-datareader>=0.2 in /usr/local/lib/python3.7/dist-packages (from empyrical>=0.5.0->pyfolio@ git+
Requirement already satisfied: six>=1.5.2 in /usr/local/lib/python3.7/dist-packages (from grpcio>=1.28.1->ray[default,tune]==1.3.0->f
Requirement already satisfied: cloudpickle>=1.2.0 in /usr/local/lib/python3.7/dist-packages (from gym>=0.17->finrl==0.3.5) (1.5.0)
Requirement already satisfied: jedi>=0.10 in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@ git+https://github
Requirement already satisfied: pickleshare in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@ git+https://githu
Requirement already satisfied: pexpect in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@ git+https://github.co
Requirement already satisfied: traitlets>=4.2 in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@ git+https://gi
Requirement already satisfied: prompt-toolkit<2.1.0,>=2.0.0 in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@
Requirement already satisfied: pygments in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@ git+https://github.c
Requirement already satisfied: backcall in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@ git+https://github.c
Requirement already satisfied: decorator in /usr/local/lib/python3.7/dist-packages (from ipython>=3.2.3->pyfolio@ git+https://github.
Requirement already satisfied: parso<0.9.0,>=0.8.0 in /usr/local/lib/python3.7/dist-packages (from jedi>=0.10->ipython>=3.2.3->pyfoli
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.7/dist-packages (from matplotlib->finrl==0.3.5) (0.11.0)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->finrl==0.3.5) (1.4.4)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in /usr/local/lib/python3.7/dist-packages (from matplotlib->f
Requirement already satisfied: lxml in /usr/local/lib/python3.7/dist-packages (from pandas-datareader>=0.2->empyrical>=0.5.0->pyfolio
Requirement already satisfied: wcwidth in /usr/local/lib/python3.7/dist-packages (from prompt-toolkit<2.1.0,>=2.0.0->ipython>=3.2.3->
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.7/dist-packages (from requests->ray[default,tune]==1.3.0->finrl
Requirement already satisfied: joblib>=0.11 in /usr/local/lib/python3.7/dist-packages (from scikit-learn>=0.21.0->finrl==0.3.5) (1.2.
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.7/dist-packages (from scikit-learn>=0.21.0->finrl==0.3.
Requirement already satisfied: blessed>=1.17.1 in /usr/local/lib/python3.7/dist-packages (from gpustat->ray[default,tune]==1.3.0->fin
Requirement already satisfied: nvidia-ml-py<=11.495.46,>=11.450.129 in /usr/local/lib/python3.7/dist-packages (from gpustat->ray[defa
Requirement already satisfied: psutil>=5.6.0 in /usr/local/lib/python3.7/dist-packages (from gpustat->ray[default,tune]==1.3.0->finrl
Requirement already satisfied: SQLAlchemy>=1.2.8 in /usr/local/lib/python3.7/dist-packages (from jqdatasdk->finrl==0.3.5) (1.4.44)
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Requirement already satisfied: thriftpy2>=0.3.9 in /usr/local/lib/python3.7/dist-packages (from jqdatasdk->finrl==0.3.5) (0.4.16)
Requirement already satisfied: greenlet!=0.4.17 in /usr/local/lib/python3.7/dist-packages (from SQLAlchemy>=1.2.8->jqdatasdk->finrl==
Requirement already satisfied: ply<4.0,>=3.4 in /usr/local/lib/python3.7/dist-packages (from thriftpy2>=0.3.9->jqdatasdk->finrl==0.3.
Requirement already satisfied: pyrsistent!=0.17.0,!=0.17.1,!=0.17.2,>=0.14.0 in /usr/local/lib/python3.7/dist-packages (from jsonsche
Requirement already satisfied: importlib-resources>=1.4.0 in /usr/local/lib/python3.7/dist-packages (from jsonschema->ray[default,tun
Requirement already satisfied: google-api-core<3.0.0,>=1.0.0 in /usr/local/lib/python3.7/dist-packages (from opencensus->ray[default,
Requirement already satisfied: opencensus-context>=0.1.3 in /usr/local/lib/python3.7/dist-packages (from opencensus->ray[default,tune
Requirement already satisfied: googleapis-common-protos<2.0dev,>=1.56.2 in /usr/local/lib/python3.7/dist-packages (from google-api-co
Requirement already satisfied: google-auth<3.0dev,>=1.25.0 in /usr/local/lib/python3.7/dist-packages (from google-api-core<3.0.0,>=1.
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.7/dist-packages (from google-auth<3.0dev,>=1.25.0->google-api-
Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/python3.7/dist-packages (from google-auth<3.0dev,>=1.25.0->goo
Requirement already satisfied: cachetools<6.0,>=2.0.0 in /usr/local/lib/python3.7/dist-packages (from google-auth<3.0dev,>=1.25.0->go
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in /usr/local/lib/python3.7/dist-packages (from pyasn1-modules>=0.2.1->google-aut
Requirement already satisfied: ptyprocess>=0.5 in /usr/local/lib/python3.7/dist-packages (from pexpect->ipython>=3.2.3->pyfolio@ git+
Requirement already satisfied: multitasking>=0.0.7 in /usr/local/lib/python3.7/dist-packages (from yfinance->finrl==0.3.5) (0.0.11)
Requirement already satisfied: appdirs>=1.4.4 in /usr/local/lib/python3.7/dist-packages (from yfinance->finrl==0.3.5) (1.4.4)
```

```
!pip install wrds
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Requirement already satisfied: wrds in /usr/local/lib/python3.7/dist-packages (3.1.2)
Requirement already satisfied: pandas in /usr/local/lib/python3.7/dist-packages (from wrds) (1.3.5)
Requirement already satisfied: mock in /usr/local/lib/python3.7/dist-packages (from wrds) (4.0.3)
Requirement already satisfied: sqlalchemy in /usr/local/lib/python3.7/dist-packages (from wrds) (1.4.44)
Requirement already satisfied: numpy in /usr/local/lib/python3.7/dist-packages (from wrds) (1.21.6)
Requirement already satisfied: psycopg2-binary in /usr/local/lib/python3.7/dist-packages (from wrds) (2.9.5)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-packages (from pandas->wrds) (2022.6)
Requirement already satisfied: python-dateutil>=2.7.3 in /usr/local/lib/python3.7/dist-packages (from pandas->wrds) (2.8.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.7/dist-packages (from python-dateutil>=2.7.3->pandas->wrds) (1.15.0)
Requirement already satisfied: greenlet!=0.4.17 in /usr/local/lib/python3.7/dist-packages (from sqlalchemy->wrds) (2.0.1)
Requirement already satisfied: importlib-metadata in /usr/local/lib/python3.7/dist-packages (from sqlalchemy->wrds) (4.13.0)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata->sqlalchemy->wrds) (3.10.0)
Requirement already satisfied: typing-extensions>=3.6.4 in /usr/local/lib/python3.7/dist-packages (from importlib-metadata->sqlalchemy->
```

```
import pandas as pd
import numpy as np
```

```
import matplotlib
import matplotlib.pyplot as plt
# matplotlib.use('Agg')
import datetime
import plotly.express as px
import seaborn as sns

%matplotlib inline
from finrl import config
from finrl import config_tickers
from finrl.meta.preprocessor.yahoodownloader import YahooDownloader
from finrl.meta.preprocessor.preprocessors import FeatureEngineer, data_split
from finrl.meta.env_stock_trading.env_stocktrading import StockTradingEnv
from finrl.agents.stablebaselines3.models import DRLAgent
from finrl.plot import backtest_stats, backtest_plot, get_daily_return, get_baseline
from finrl.main import check_and_make_directories
from pprint import pprint
from stable_baselines3.common.logger import configure
import sys
sys.path.append("../FinRL")

import itertools

from finrl.config import (
    DATA_SAVE_DIR,
    TRAINED_MODEL_DIR,
    TENSORBOARD_LOG_DIR,
    RESULTS_DIR,
    INDICATORS,
    TRAIN_START_DATE,
    TRAIN_END_DATE,
    TEST_START_DATE,
    TEST_END_DATE,
    TRADE_START_DATE,
    TRADE_END_DATE,
)

from finrl.config_tickers import DOW_30_TICKER
```

```
check_and_make_directories([DATA_SAVE_DIR, TRAINED_MODEL_DIR, TENSORBOARD_LOG_DIR, RESULTS_DIR])
```

```
print(DOW_30_TICKER)
```

```
['AXP', 'AMGN', 'AAPL', 'BA', 'CAT', 'CSCO', 'CVX', 'GS', 'HD', 'HON', 'IBM', 'INTC', 'JNJ', 'KO', 'JPM', 'MCD', 'MMM', 'MRK', 'MSFT',
```

```
TRAIN_START_DATE = '2000-01-01'
TRAIN_END_DATE = '2018-12-31'
TEST_START_DATE = '2019-01-01'
TEST_END_DATE = '2021-12-31'

df = YahooDownloader(start_date = TRAIN_START_DATE,
                     end_date = TEST_END_DATE,
                     ticker_list = DOW_30_TICKER).fetch_data()
```

```
[*********************100%***********************]  1 of 1 completed
[*********************100%***********************]  1 of 1 completed
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```

```
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Shape of DataFrame:  (158033, 8)
```
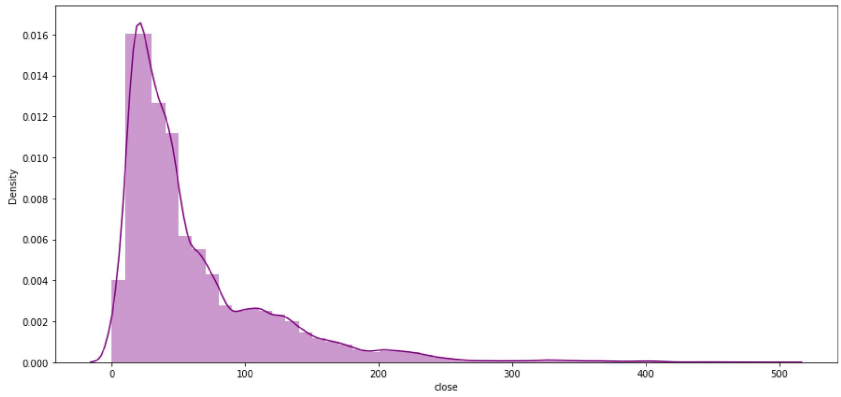
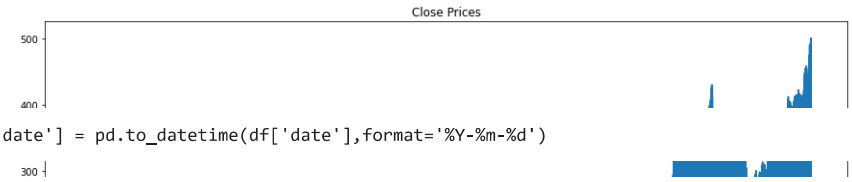

```
print(df.head())
```

```
         date       open       high        low      close     volume   tic  \
0  2000-01-03   0.936384   1.004464   0.907924   0.851942  535796800  AAPL
1  2000-01-03  70.000000  70.000000  62.875000  47.178246   22914900  AMGN
2  2000-01-03  47.995617  47.995617  45.515598  33.552006    6471267   AXP
3  2000-01-03  41.437500  41.687500  39.812500  25.940281    2638200    BA
4  2000-01-03  23.843750  24.500000  23.843750  13.234138    5055000   CAT

   day
0    0
1    0
2    0
3    0
4    0
```

```
plt.figure(figsize=(15,7))
sns.distplot(df['close'].dropna(), bins=50, color='purple');
```




```
sma5 = df['close'].rolling(5).mean() #5 days
sma100 = df['close'].rolling(100).mean() #100 days

AAPL_sma = pd.DataFrame({'AAPL': df['close'], 'SMA 5': sma5, 'SMA 100': sma100})
AAPL_sma.plot(figsize=(15, 7), legend=False, title='Close Prices');
```




```
df['date'] = pd.to_datetime(df['date'],format='%Y-%m-%d')
```

```
df.sort_values(['date','tic'],ignore_index=True).head()
```

	date	open	high	low	close	volume	tic	day
0	2000-01-03	0.936384	1.004464	0.907924	0.851942	535796800	AAPL	0
1	2000-01-03	70.000000	70.000000	62.875000	47.178246	22914900	AMGN	0
2	2000-01-03	47.995617	47.995617	45.515598	33.552006	6471267	AXP	0
3	2000-01-03	41.437500	41.687500	39.812500	25.940281	2638200	BA	0
4	2000-01-03	23.843750	24.500000	23.843750	13.234138	5055000	CAT	0

```
df_new = df.set_index("date")
```

```
df_new
```

	open	high	low	close	volume	tic	day
date							
2000-01-03	0.936384	1.004464	0.907924	0.851942	535796800	AAPL	0
2000-01-03	70.000000	70.000000	62.875000	47.178246	22914900	AMGN	0
2000-01-03	47.995617	47.995617	45.515598	33.552006	6471267	AXP	0
2000-01-03	41.437500	41.687500	39.812500	25.940281	2638200	BA	0
2000-01-03	23.843750	24.500000	23.843750	13.234138	5055000	CAT	0
...	...	...	...	...	...	...	...
2021-12-30	507.929993	509.230011	503.649994	499.586884	1309800	UNH	3
2021-12-30	217.970001	219.149994	217.149994	216.234314	3812800	V	3
2021-12-30	52.380001	52.570000	52.080002	49.538277	15615500	VZ	3
2021-12-30	52.360001	52.919998	51.939999	49.691002	3653600	WBA	3
2021-12-30	143.259995	143.699997	142.479996	141.485672	4983000	WMT	3

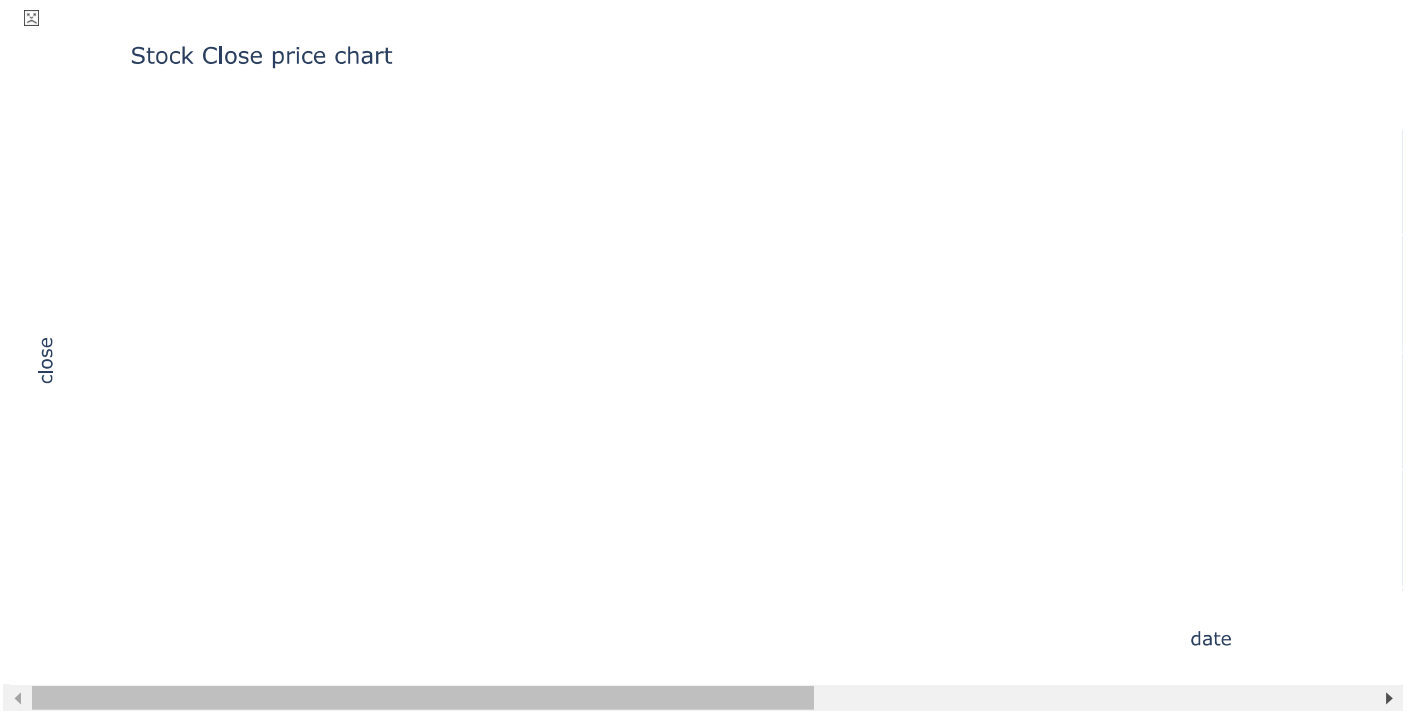
158033 rows × 7 columns

```
AAPL = df_new[df_new['tic']== "AAPL"]

fig = px.line(AAPL,  y ="open", title='Stock Open price chart')
fig.show()
```

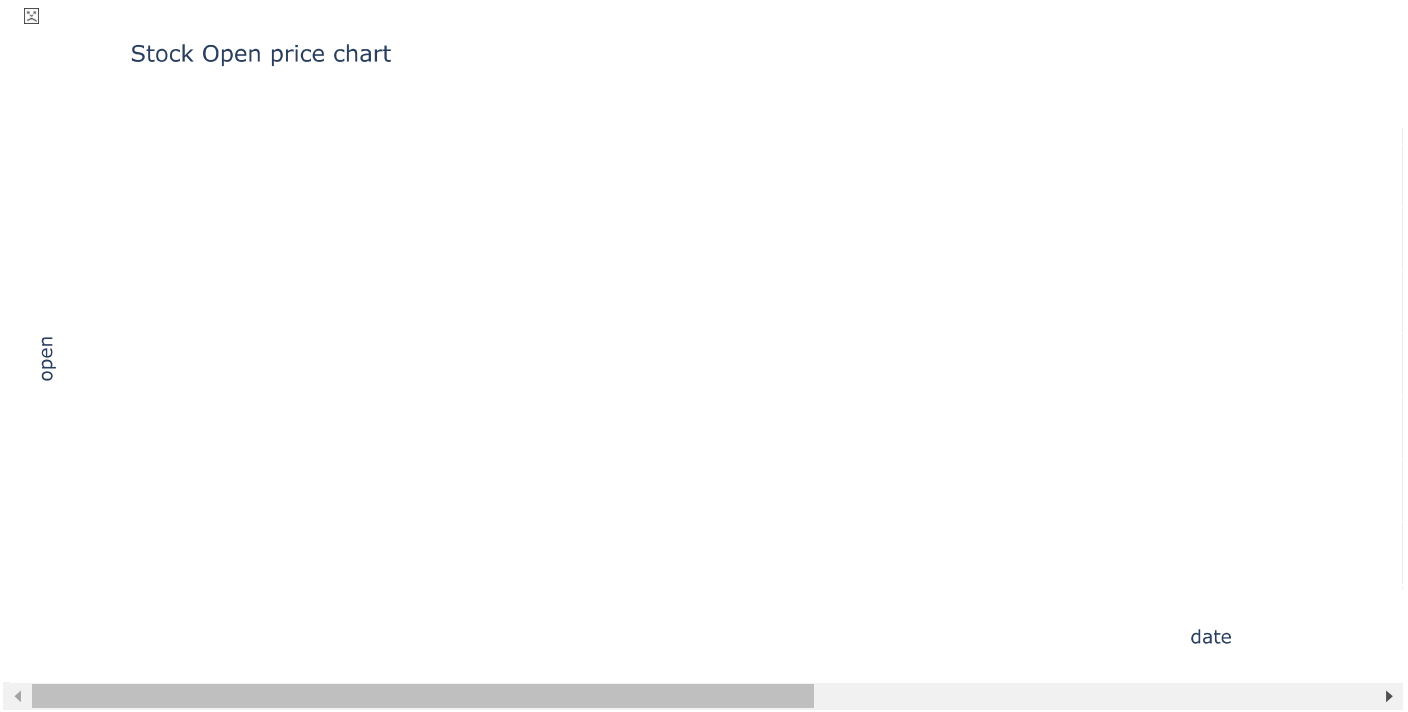

```
AAPL = df_new[df_new['tic']== "AAPL"]

fig = px.line(AAPL,  y ="close", title='Stock Close price chart')
fig.show()
```


```
AXP = df_new[df_new['tic']== "AXP"]

fig = px.line(AXP,  y ="close", title='Stock Open price chart')
fig.show()
```

```
AXP = df_new[df_new['tic']== "AXP"]

fig = px.line(AXP,  y ="close", title='Stock Close price chart')
fig.show()
```

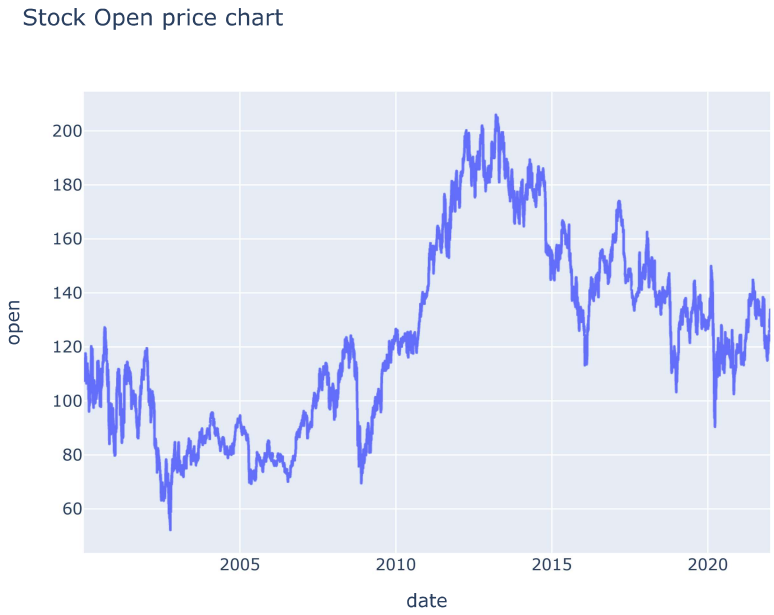



```
MSFT = df_new[df_new['tic']== "MSFT"]

fig = px.line(MSFT,  y ="open", title='Stock Open price chart')
fig.show()
```

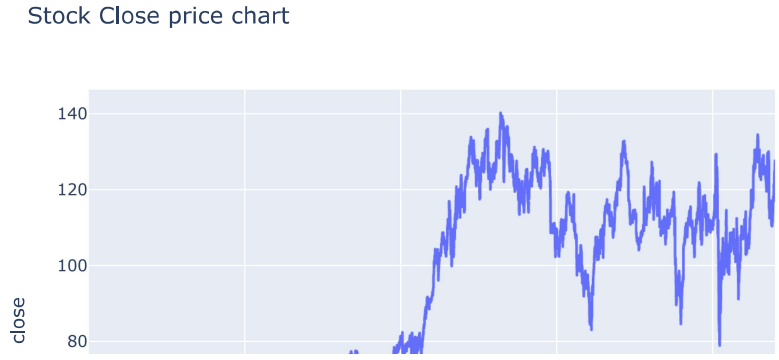



```
MSFT = df_new[df_new['tic']== "MSFT"]

fig = px.line(MSFT,  y ="close", title='Stock Close price chart')
fig.show()
```

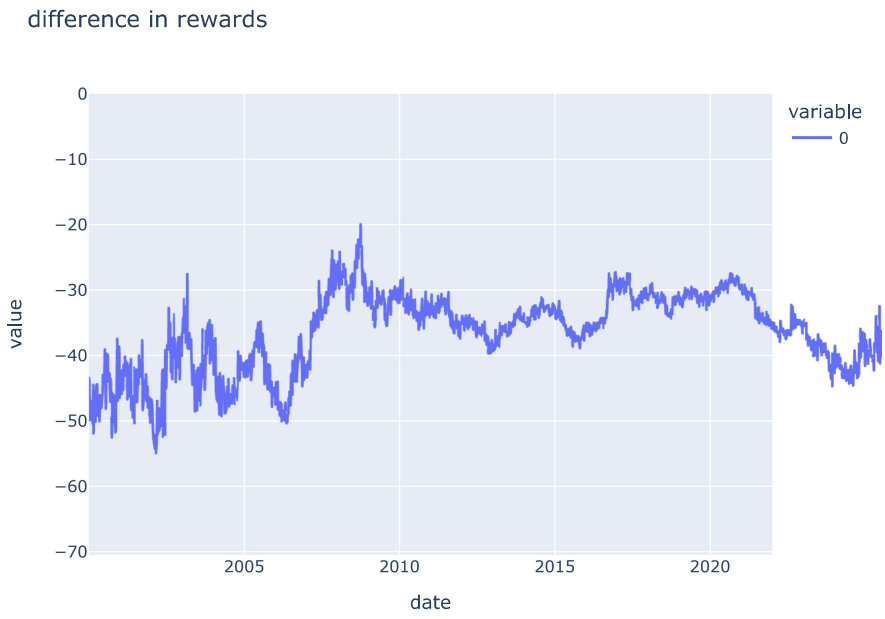

```
IBM = df_new[df_new['tic']== "IBM"]

fig = px.line(IBM,  y ="open", title='Stock Open price chart')
fig.show()
```




```
IBM = df_new[df_new['tic']== "IBM"]

fig = px.line(IBM,  y ="close", title='Stock Close price chart')
fig.show()
```

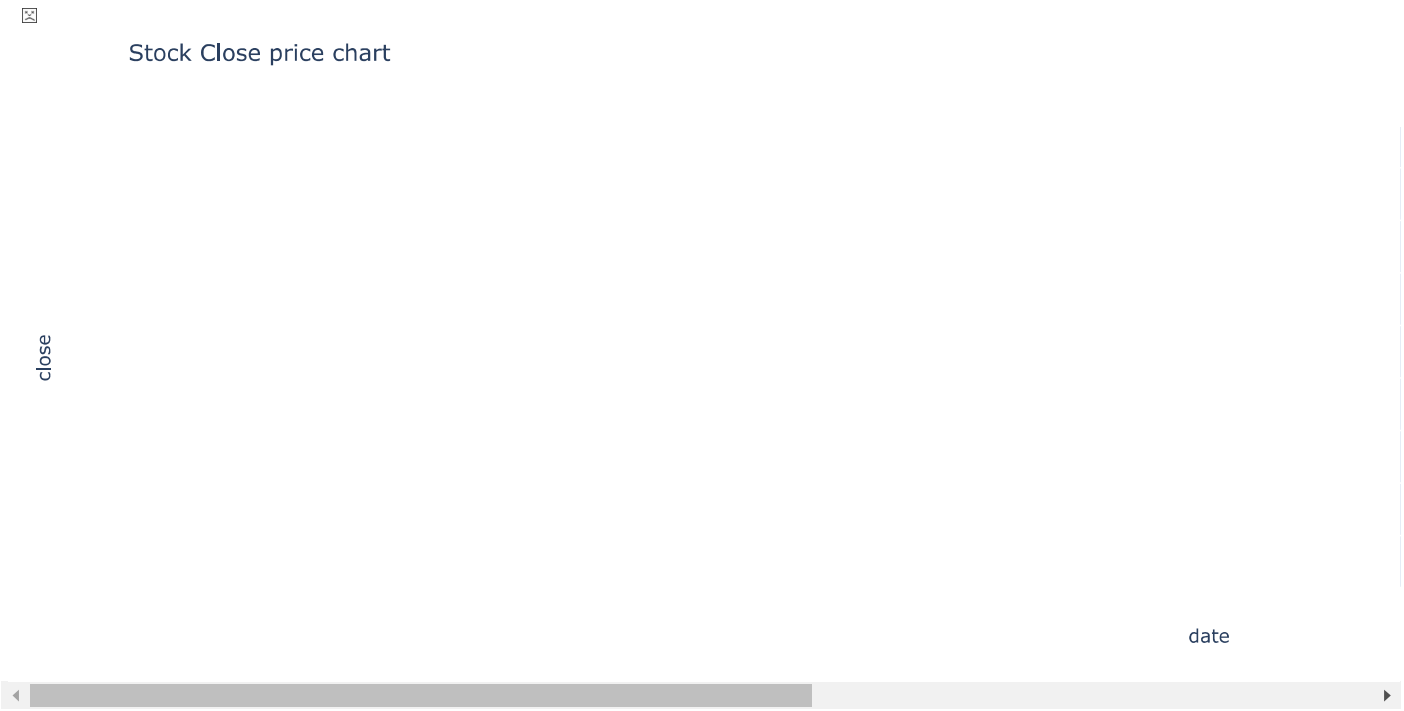



```
reward = IBM['close'] - IBM['open']

fig = px.line(reward, title='difference in rewards')
fig.show()
```

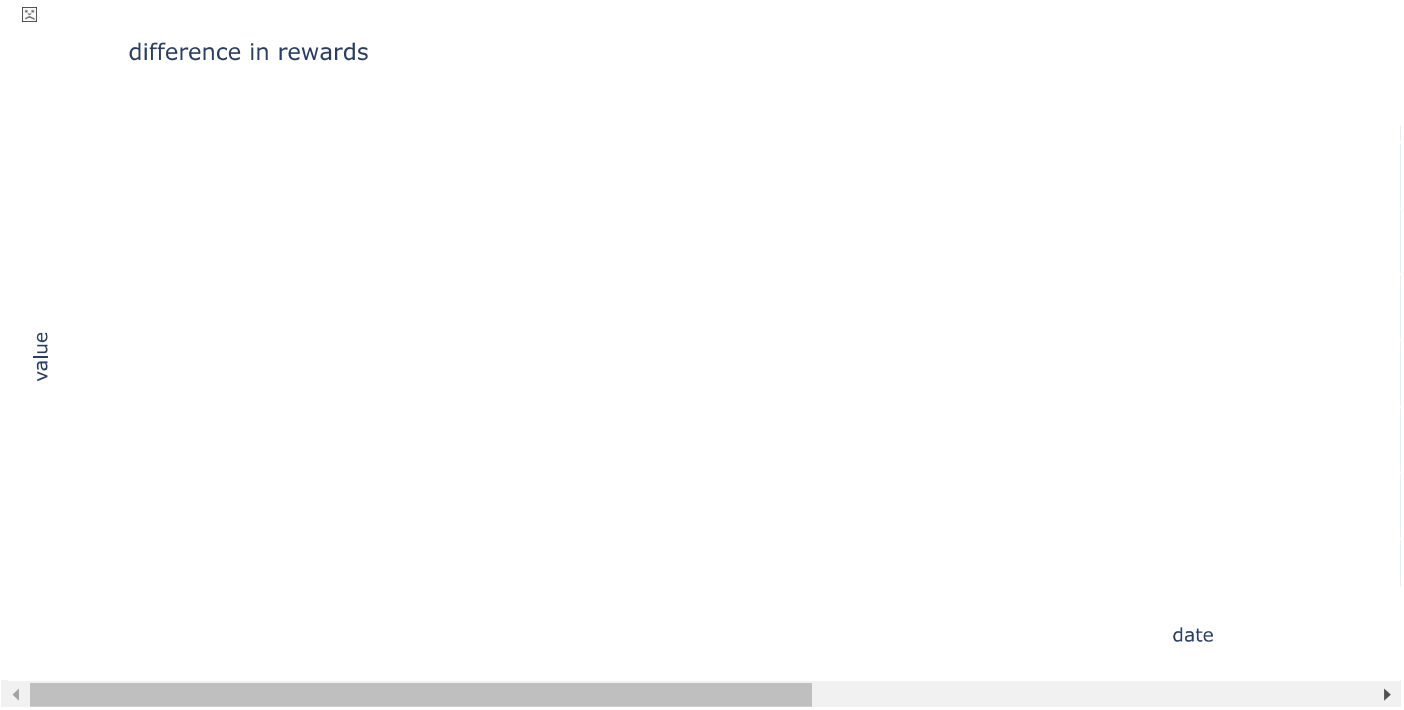



```
JPM = df_new[df_new['tic']== "JPM"]

fig = px.line(JPM,  y ="open", title='Stock Open price chart')
fig.show()
```


```
JPM = df_new[df_new['tic']== "JPM"]

fig = px.line(JPM,  y ="close", title='Stock Close price chart')
fig.show()
```




```
reward = JPM['close'] - JPM['open']

fig = px.line(reward, title='difference in rewards')
fig.show()
```



```
url = 'D:\Users\HP\Downloads\dow_30_fundamental_wrds.csv'

available_fund = pd.read_csv(url)
print(available_fund.head())
```

```
   gvkey  datadate  fyearq  fqtr  fyr indfmt consol popsrc datafmt  tic  ...  \
0   1447  19990630    1999     2   12   INDL      C      D     STD  AXP  ...
1   1447  19990930    1999     3   12   INDL      C      D     STD  AXP  ...
2   1447  19991231    1999     4   12   INDL      C      D     STD  AXP  ...
3   1447  20000331    2000     1   12   INDL      C      D     STD  AXP  ...
4   1447  20000630    2000     2   12   INDL      C      D     STD  AXP  ...

  dvpsxq mkvaltq     prccq     prchq     prclq  adjex ggroup    gind gsector  \
0  0.225     NaN  130.1250  142.6250  114.5000    3.0   4020  402020      40
1  0.000     NaN  135.0000  150.6250  121.8750    3.0   4020  402020      40
2  0.225     NaN  166.2500  168.8750  130.2500    3.0   4020  402020      40
3  0.225     NaN  148.9375  169.5000  119.5000    3.0   4020  402020      40
4  0.080     NaN   52.1250   57.1875   43.9375    1.0   4020  402020      40

    gsubind
0  40202010
1  40202010
2  40202010
3  40202010
4  40202010

[5 rows x 647 columns]
/usr/local/lib/python3.7/dist-packages/IPython/core/interactiveshell.py:3326: DtypeWarning:

Columns (16,25) have mixed types.Specify dtype option on import or set low_memory=False.
```

```
items = [
    'datadate', # Date
    'tic', # Ticker
    'oiadpq', # Quarterly operating income
    'revtq', # Quartely revenue
    'niq', # Quartely net income
    'atq', # Total asset
    'teqq', # Shareholder's equity
    'epspiy', # EPS(Basic) incl. Extraordinary items
    'ceqq', # Common Equity
    'cshoq', # Common Shares Outstanding
    'dvpspq', # Dividends per share
    'actq', # Current assets
    'lctq', # Current liabilities
    'cheq', # Cash & Equivalent
    'rectq', # Recievalbles
    'cogsq', # Cost of  Goods Sold
    'invtq', # Inventories
    'apq',# Account payable
    'dlttq', # Long term debt
    'dlcq', # Debt in current liabilites
    'ltq' # Liabilities
]

# Omit items that will not be used
fund_data = available_fund[items]


fund_data = fund_data.rename(columns={
    'datadate':'date', # Date
    'oiadpq':'qopincome', # Quarterly operating income
    'revtq':'quarter_rev', # Quartely revenue
    'niq':'quarter_netinc', # Quartely net income
    'atq':'totalassets', # Assets
    'teqq':'sh_equity', # Shareholder's equity
    'epspiy':'eps_incl_ex', # EPS(Basic) incl. Extraordinary items
    'ceqq':'common_equity', # Common Equity
    'cshoq':'share_outstanding', # Common Shares Outstanding
    'dvpspq':'dividend_sh', # Dividends per share
    'actq':'current_assets', # Current assets
    'lctq':'current_liabilities', # Current liabilities
    'cheq':'cash_available', # Cash & Equivalent
    'rectq':'receivables', # Receivalbles
    'cogsq':'cost_goods_sold', # Cost of  Goods Sold
    'invtq':'inventories', # Inventories
    'apq': 'payables',# Account payable
    'dlttq':'long_term_debt', # Long term debt
```

```
    'dlcq':'short_term_debt', # Debt in current liabilites
    'ltq':'total_liabilities' # Liabilities
})

print(fund_data.head())
```

```
         date  tic  qopincome  quarter_rev  quarter_netinc  totalassets  \
0  19990630  AXP      896.0       5564.0           646.0     132452.0
1  19990930  AXP      906.0       5584.0           648.0     132616.0
2  19991231  AXP      845.0       6009.0           606.0     148517.0
3  20000331  AXP      920.0       6021.0           656.0     150662.0
4  20000630  AXP     1046.0       6370.0           740.0     148553.0

   sh_equity  eps_incl_ex  common_equity  share_outstanding  ...  \
0     9762.0         2.73         9762.0              449.0  ...
1     9744.0         4.18         9744.0              447.6  ...
2    10095.0         5.54        10095.0              446.9  ...
3    10253.0         1.48        10253.0              444.7  ...
4    10509.0         1.05        10509.0             1333.0  ...

   current_assets  current_liabilities  cash_available  receivables  \
0             NaN                  NaN          6096.0      46774.0
1             NaN                  NaN          5102.0      48827.0
2             NaN                  NaN         10391.0      54033.0
3             NaN                  NaN          7425.0      53663.0
4             NaN                  NaN          6841.0      54286.0

   cost_goods_sold  inventories  payables  long_term_debt  short_term_debt  \
0           4668.0        448.0   22282.0          7005.0          24785.0
1           4678.0        284.0   23587.0          6720.0          24683.0
2           5164.0        277.0   25719.0          4685.0          32437.0
3           5101.0        315.0   26379.0          5670.0          29342.0
4           5324.0        261.0   29536.0          5336.0          26170.0

   total_liabilities
0           122690.0
1           122872.0
2           138422.0
3           140409.0
4           138044.0

[5 rows x 21 columns]
```

```
date = pd.to_datetime(fund_data['date'],format='%Y%m%d')

tic = fund_data['tic'].to_frame('tic')

# Profitability ratios
# Operating Margin
operating_margin = pd.Series(np.empty(fund_data.shape[0],dtype=object),name='operating_margin')
for i in range(0, fund_data.shape[0]):
    if i-3 < 0:
        operating_margin[i] = np.nan
    elif fund_data.iloc[i,1] != fund_data.iloc[i-3,1]:
        operating_margin.iloc[i] = np.nan
    else:
        operating_margin.iloc[i] = np.sum(fund_data['qopincome'].iloc[i-3:i])/np.sum(fund_data['quarter_rev'].iloc[i-3:i])

# Net Profit Margin
net_profit_margin = pd.Series(np.empty(fund_data.shape[0],dtype=object),name='net_profit_margin')
for i in range(0, fund_data.shape[0]):
    if i-3 < 0:
        net_profit_margin[i] = np.nan
    elif fund_data.iloc[i,1] != fund_data.iloc[i-3,1]:
        net_profit_margin.iloc[i] = np.nan
    else:
        net_profit_margin.iloc[i] = np.sum(fund_data['quarter_netinc'].iloc[i-3:i])/np.sum(fund_data['quarter_rev'].iloc[i-3:i])

# Return On Assets
return_over_assests = pd.Series(np.empty(fund_data.shape[0],dtype=object),name='return_over_assests')
for i in range(0, fund_data.shape[0]):
    if i-3 < 0:
        return_over_assests[i] = np.nan
    elif fund_data.iloc[i,1] != fund_data.iloc[i-3,1]:
        return_over_assests.iloc[i] = np.nan
    else:
        return_over_assests.iloc[i] = np.sum(fund_data['quarter_netinc'].iloc[i-3:i])/fund_data['totalassets'].iloc[i]

# Return on Equity
return_on_equity = pd.Series(np.empty(fund_data.shape[0],dtype=object),name='return_on_equity')
```

```
for i in range(0, fund_data.shape[0]):
    if i-3 < 0:
        return_on_equity[i] = np.nan
    elif fund_data.iloc[i,1] != fund_data.iloc[i-3,1]:
        return_on_equity.iloc[i] = np.nan
    else:
        return_on_equity.iloc[i] = np.sum(fund_data['quarter_netinc'].iloc[i-3:i])/fund_data['sh_equity'].iloc[i]

# For calculating valuation ratios in the next subpart, calculate per share items in advance
# Earnings Per Share
earnings_per_share = fund_data['eps_incl_ex'].to_frame('earnings_per_share')

# Book Per Share
book_per_share = (fund_data['common_equity']/fund_data['share_outstanding']).to_frame('book_per_share') # Need to check units

#Dividend Per Share
dividend_per_share = fund_data['dividend_sh'].to_frame('dividend_per_share')

# Liquidity ratios
# Current ratio
current_ratio = (fund_data['current_assets']/fund_data['current_liabilities']).to_frame('current_ratio')

# Quick ratio
quick_ratio = ((fund_data['cash_available'] + fund_data['receivables'] )/fund_data['current_liabilities']).to_frame('quick_ratio')

# Cash ratio
cash_ratio = (fund_data['cash_available']/fund_data['current_liabilities']).to_frame('cash_ratio')


# Efficiency ratios
# Inventory turnover ratio
inventory_turnover = pd.Series(np.empty(fund_data.shape[0],dtype=object),name='inventory_turnover')
for i in range(0, fund_data.shape[0]):
    if i-3 < 0:
        inventory_turnover[i] = np.nan
    elif fund_data.iloc[i,1] != fund_data.iloc[i-3,1]:
        inventory_turnover.iloc[i] = np.nan
    else:
        inventory_turnover.iloc[i] = np.sum(fund_data['cost_goods_sold'].iloc[i-3:i])/fund_data['inventories'].iloc[i]

# Receivables turnover ratio
receivable_turnover = pd.Series(np.empty(fund_data.shape[0],dtype=object),name='receivable_turnover')
for i in range(0, fund_data.shape[0]):
    if i-3 < 0:
        receivable_turnover[i] = np.nan
    elif fund_data.iloc[i,1] != fund_data.iloc[i-3,1]:
        receivable_turnover.iloc[i] = np.nan
    else:
        receivable_turnover.iloc[i] = np.sum(fund_data['quarter_rev'].iloc[i-3:i])/fund_data['receivables'].iloc[i]

# Payable turnover ratio
payable_turnover = pd.Series(np.empty(fund_data.shape[0],dtype=object),name='payable_turnover')
for i in range(0, fund_data.shape[0]):
    if i-3 < 0:
        payable_turnover[i] = np.nan
    elif fund_data.iloc[i,1] != fund_data.iloc[i-3,1]:
        payable_turnover.iloc[i] = np.nan
    else:
        payable_turnover.iloc[i] = np.sum(fund_data['cost_goods_sold'].iloc[i-3:i])/fund_data['payables'].iloc[i]

## Leverage financial ratios
# Debt ratio
debt_ratio = (fund_data['total_liabilities']/fund_data['totalassets']).to_frame('debt_ratio')

# Debt to Equity ratio
debt_to_equity = (fund_data['total_liabilities']/fund_data['sh_equity']).to_frame('debt_to_equity')
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:14: RuntimeWarning:

divide by zero encountered in double_scalars

/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:14: RuntimeWarning:

invalid value encountered in double_scalars

/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:24: RuntimeWarning:

divide by zero encountered in double_scalars
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:24: RuntimeWarning:

invalid value encountered in double_scalars

/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:76: RuntimeWarning:

divide by zero encountered in double_scalars

/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:76: RuntimeWarning:

invalid value encountered in double_scalars
```

```
ratios = pd.concat([date,tic,operating_margin,net_profit_margin,return_over_assests,return_on_equity,earnings_per_share,book_per_share,divide
                    current_ratio,quick_ratio,cash_ratio,inventory_turnover,receivable_turnover,payable_turnover,
                   debt_ratio,debt_to_equity], axis=1)
print(ratios.head())
```

```
        date  tic operating_margin net_profit_margin return_over_assests  \
0 1999-06-30  AXP              NaN               NaN                 NaN
1 1999-09-30  AXP              NaN               NaN                 NaN
2 1999-12-31  AXP              NaN               NaN                 NaN
3 2000-03-31  AXP         0.154281          0.110742            0.012611
4 2000-06-30  AXP         0.151641          0.108436            0.012857

  return_on_equity  earnings_per_share  book_per_share  dividend_per_share  \
0              NaN                2.73       21.741648               0.225
1              NaN                4.18       21.769437               0.225
2              NaN                5.54       22.588946               0.225
3         0.185312                1.48       23.055993               0.225
4         0.181749                1.05        7.883721               0.080

   current_ratio  quick_ratio  cash_ratio inventory_turnover  \
0            NaN          NaN         NaN               NaN
1            NaN          NaN         NaN               NaN
2            NaN          NaN         NaN               NaN
3            NaN          NaN         NaN         46.063492
4            NaN          NaN         NaN         57.252874

  receivable_turnover payable_turnover  debt_ratio  debt_to_equity
0                 NaN              NaN    0.926298       12.568121
1                 NaN              NaN    0.926525       12.610016
2                 NaN              NaN    0.932028       13.711937
3            0.319717         0.550059    0.931947       13.694431
4            0.324467         0.505925    0.929258       13.135788
```

```
ratios_final = ratios.copy()
ratios_final = ratios_final.fillna(0)
ratios_final = ratios_final.replace(np.inf,0)
print(ratios_final.head())
```

```
        date  tic  operating_margin  net_profit_margin  return_over_assests  \
0 1999-06-30  AXP          0.000000           0.000000             0.000000
1 1999-09-30  AXP          0.000000           0.000000             0.000000
2 1999-12-31  AXP          0.000000           0.000000             0.000000
3 2000-03-31  AXP          0.154281           0.110742             0.012611
4 2000-06-30  AXP          0.151641           0.108436             0.012857

   return_on_equity  earnings_per_share  book_per_share  dividend_per_share  \
0          0.000000                2.73       21.741648               0.225
1          0.000000                4.18       21.769437               0.225
2          0.000000                5.54       22.588946               0.225
3          0.185312                1.48       23.055993               0.225
4          0.181749                1.05        7.883721               0.080

   current_ratio  quick_ratio  cash_ratio  inventory_turnover  \
0            0.0          0.0         0.0            0.000000
1            0.0          0.0         0.0            0.000000
2            0.0          0.0         0.0            0.000000
3            0.0          0.0         0.0           46.063492
4            0.0          0.0         0.0           57.252874

   receivable_turnover  payable_turnover  debt_ratio  debt_to_equity
0             0.000000          0.000000    0.926298       12.568121
1             0.000000          0.000000    0.926525       12.610016
2             0.000000          0.000000    0.932028       13.711937
3             0.319717          0.550059    0.931947       13.694431
4             0.324467          0.505925    0.929258       13.135788
```

```
list_ticker = df["tic"].unique().tolist()
list_date = list(pd.date_range(df['date'].min(),df['date'].max()))
ticker_date = list(itertools.product(list_date,list_ticker))

# Merge stock price data and ratios into one dataframe
stock_data_final = pd.DataFrame(ticker_date,columns=["date","tic"]).merge(df,on=["date","tic"],how="left")
stock_data_final = stock_data_final.merge(ratios_final,how='left',on=['date','tic'])
stock_data_final = stock_data_final.sort_values(['tic','date'])

# Backfill the ratio data to make them daily
stock_data_final = stock_data_final.bfill(axis='rows')


# Calculate P/E, P/B and dividend yield using daily closing price
stock_data_final['PE'] = stock_data_final['close']/stock_data_final['earnings_per_share']
stock_data_final['PB'] = stock_data_final['close']/stock_data_final['book_per_share']
stock_data_final['Div_yield'] = stock_data_final['dividend_per_share']/stock_data_final['close']

# Drop per share items used for the above calculation
stock_data_final = stock_data_final.drop(columns=['day','earnings_per_share','book_per_share','dividend_per_share'])
# Replace NAs infinite values with zero
stock_data_final = stock_data_final.copy()
stock_data_final = stock_data_final.fillna(0)
stock_data_final = stock_data_final.replace(np.inf,0)


stock_data_final.sort_values(['date','tic'],ignore_index=True).head(10)
```

	date	tic	open	high	low	close	volume	operating_margin	net_profit_margin	return_over_assests	...	qu
0	2000-01-03	AAPL	0.936384	1.004464	0.907924	0.851942	535796800.0	0.070460	0.094902	0.070929	...	
1	2000-01-03	AMGN	70.000000	70.000000	62.875000	47.178246	22914900.0	0.154281	0.110742	0.012611	...	
2	2000-01-03	AXP	47.995617	47.995617	45.515598	33.552006	6471267.0	0.154281	0.110742	0.012611	...	
3	2000-01-03	BA	41.437500	41.687500	39.812500	25.940281	2638200.0	0.053852	0.042201	0.050328	...	
4	2000-01-03	CAT	23.843750	24.500000	23.843750	13.234138	5055000.0	0.106033	0.049949	0.027482	...	
5	2000-01-03	CRM	3.750000	4.325000	3.687500	4.300000	43574400.0	0.000000	0.000000	0.000000	...	
6	2000-01-03	CSCO	54.968750	55.125000	51.781250	38.369190	53076000.0	0.000000	0.000000	0.000000	...	
7	2000-01-03	CVX	42.937500	42.937500	41.281250	18.007635	4387600.0	0.101839	0.066830	0.042207	...	
8	2000-01-03	DIS	28.855125	29.533344	28.361876	23.115253	8402230.0	0.127642	0.042000	0.016826	...	
9	2000-01-03	DOW	52.750000	53.500000	49.500000	40.797009	2350800.0	0.000000	0.000000	0.000000	...	

10 rows × 22 columns

```
stock_training = data_split(stock_data_final, TRAIN_START_DATE, TRAIN_END_DATE)
stock_testing = data_split(stock_data_final, TEST_START_DATE, TEST_END_DATE)

print(len(stock_training))
print(len(stock_testing))
```

```
208110
32850
```

```
print(stock_training.head())
print(stock_testing)
```

```
0     148158800.0          0.258891          0.227773             0.133360
0       3009100.0          0.154281          0.110742             0.012611
0       4175400.0          0.203479          0.160494             0.026811
0       3292200.0          0.116496          0.102682             0.066409
0       4783200.0          0.186871          0.107064             0.056932
...           ...               ...               ...                  ...
1094    1309800.0          0.000000          0.000000             0.000000
1094    3812800.0          0.253337          0.143100             0.094138
1094   15615500.0          0.000000          0.000000             0.000000
1094    3653600.0          0.000000          0.000000             0.000000
1094    4983000.0          0.000000          0.000000             0.000000

      ...  quick_ratio  cash_ratio  inventory_turnover  receivable_turnover  \
0     ...     1.134347    0.854114           23.571867             7.620024
0     ...     0.000000    0.000000           46.063492             0.319717
0     ...     0.000000    0.000000            0.000000             0.231669
0     ...     0.262465    0.092436            0.933164             5.468453
0     ...     0.919490    0.266175            2.135008             2.339630
...   ...          ...         ...                 ...                  ...
1094  ...     0.000000    0.000000            0.000000             0.000000
1094  ...     0.564506    0.069086           42.371817             6.132957
1094  ...     0.311515    0.005755            0.000000             0.000000
1094  ...     0.123900    0.071930            0.000000             0.000000
1094  ...     0.000000    0.000000            0.000000             0.000000

      payable_turnover  debt_ratio  debt_to_equity          PE           PB  \
0             3.781658    0.690466        2.230663    5.687334     1.658428
0             0.550059    0.931947       13.694431  115.139554     7.390987
0             0.279424    0.887329        7.875371   49.946531     3.405684
0             4.151637    0.998070      517.142241   83.019826  1418.196271
0             3.660183    0.803394        4.086316   34.704376     4.228506
...                ...         ...             ...         ...          ...
1094          0.000000    0.000000        0.000000    0.000000     0.000000
1094          3.565286    0.738721        0.000000  393.153298    20.095230
1094          0.000000    0.402061        0.000000  137.606324    13.009158
1094          0.000000    0.614593        0.000000   41.066944     8.572919
1094          0.000000    0.000000        0.000000    0.000000     0.000000

      Div_yield
0      0.019158
0      0.001320
0      0.004314
0      0.006531
0      0.007532
...         ...
1094   0.000000
1094   0.001780
1094   0.000682
1094   0.001006
1094   0.000000

[32850 rows x 22 columns]
```

```
import gym
import matplotlib
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
from gym import spaces
from gym.utils import seeding
from stable_baselines3.common.vec_env import DummyVecEnv

matplotlib.use("Agg")



class StockTrading(gym.Env):
    """A stock trading environment for OpenAI gym"""

    metadata = {"render.modes": ["human"]}

    def __init__(
        self,
        df,
        stock_dim,
        hmax,
        initial_amount,
        buy_cost,
        sell_cost,
        rewards,
        state_space,
        action_space,
```

```
            technical_indicators,
            turbulence_threshold=None,
            risk_indicator_col="turbulence",
            make_plots=False,
            print_verbosity=10,
            day=0,
            initial=True,
            previous_state=[],
            model_name="",
            mode="",
            iteration="",
        ):
            self.day = day
            self.df = df
            self.stock_dim = stock_dim
            self.hmax = hmax
            self.initial_amount = initial_amount
            self.buy_cost = buy_cost
            self.sell_cost = sell_cost
            self.rewards = rewards
            self.state_space = state_space
            self.action_space = action_space
            self.technical_indicators = technical_indicators
            self.action_space = spaces.Box(low=-1, high=1, shape=(self.action_space,))
            self.observation_space = spaces.Box(
                low=-np.inf, high=np.inf, shape=(self.state_space,)
            )
            self.data = self.df.loc[self.day, :]
            self.terminal = False
            self.make_plots = make_plots
            self.print_verbosity = print_verbosity
            self.turbulence_threshold = turbulence_threshold
            self.risk_indicator_col = risk_indicator_col
            self.initial = initial
            self.previous_state = previous_state
            self.model_name = model_name
            self.mode = mode
            self.iteration = iteration
            # initalize state
            self.state = self._initiate_state()

            # initialize reward
            self.reward = 0
            self.turbulence = 0
            self.cost = 0
            self.trades = 0
            self.episode = 0
            # memorize all the total balance change
            self.asset_memory = [self.initial_amount]
            self.rewards_memory = []
            self.actions_memory = []
            self.date_memory = [self._get_date()]
            # self.reset()
            self._seed()

        def stock_selling(self, index, action):
            def normal_selling():
                if self.state[index + 1] > 0:
                    # Sell only if the price is > 0 (no missing data in this particular date)
                    # perform sell action based on the sign of the action
                    if self.state[index + self.stock_dim + 1] > 0:
                        # Sell only if current asset is > 0
                        sell_num_shares = min(
                            abs(action), self.state[index + self.stock_dim + 1]
                        )
                        sell_amount = (
                            self.state[index + 1]
                            * sell_num_shares
                            * (1 - self.sell_cost)
                        )
                        # update balance
                        self.state[0] += sell_amount

                        self.state[index + self.stock_dim + 1] -= sell_num_shares
                        self.cost += (
                            self.state[index + 1] * sell_num_shares * self.sell_cost
                        )
```

```
                    self.trades += 1
                else:
                    sell_num_shares = 0
            else:
                sell_num_shares = 0

            return sell_num_shares

        # perform sell action based on the sign of the action
        if self.turbulence_threshold is not None:
            if self.turbulence >= self.turbulence_threshold:
                if self.state[index + 1] > 0:
                    # Sell only if the price is > 0 (no missing data in this particular date)
                    # if turbulence goes over threshold, just clear out all positions
                    if self.state[index + self.stock_dim + 1] > 0:
                        # Sell only if current asset is > 0
                        sell_num_shares = self.state[index + self.stock_dim + 1]
                        sell_amount = (
                            self.state[index + 1]
                            * sell_num_shares
                            * (1 - self.sell_cost)
                        )
                        # update balance
                        self.state[0] += sell_amount
                        self.state[index + self.stock_dim + 1] = 0
                        self.cost += (
                            self.state[index + 1] * sell_num_shares * self.sell_cost
                        )
                        self.trades += 1
                    else:
                        sell_num_shares = 0
                else:
                    sell_num_shares = 0
            else:
                sell_num_shares = normal_selling()
        else:
            sell_num_shares = normal_selling()

        return sell_num_shares

    def stock_buying(self, index, action):
        def normal_buying():
            if self.state[index + 1] > 0:
                # Buy only if the price is > 0 (no missing data in this particular date)
                available_amount = self.state[0] // self.state[index + 1]
                # update balance
                buy_num_shares = min(available_amount, action)
                buy_amount = (
                    self.state[index + 1] * buy_num_shares * (1 + self.buy_cost)
                )
                self.state[0] -= buy_amount

                self.state[index + self.stock_dim + 1] += buy_num_shares

                self.cost += self.state[index + 1] * buy_num_shares * self.buy_cost
                self.trades += 1
            else:
                buy_num_shares = 0

            return buy_num_shares

        # perform buy action based on the sign of the action
        if self.turbulence_threshold is None:
            buy_num_shares = normal_buying()
        else:
            if self.turbulence < self.turbulence_threshold:
                buy_num_shares = normal_buying()
            else:
                buy_num_shares = 0
                pass

        return buy_num_shares

    def _make_plot(self):
        plt.plot(self.asset_memory, "r")
        plt.savefig("results/account_value_trade_{}.png".format(self.episode))
        plt.close()
```

```
    def step(self, actions):
        self.terminal = self.day >= len(self.df.index.unique()) - 1
        if self.terminal:
            if self.make_plots:
                self._make_plot()
            end_total_asset = self.state[0] + sum(
                np.array(self.state[1 : (self.stock_dim + 1)])
                * np.array(self.state[(self.stock_dim + 1) : (self.stock_dim * 2 + 1)])
            )
            df_total_value = pd.DataFrame(self.asset_memory)
            tot_reward = (
                self.state[0]
                + sum(
                    np.array(self.state[1 : (self.stock_dim + 1)])
                    * np.array(
                        self.state[(self.stock_dim + 1) : (self.stock_dim * 2 + 1)]
                    )
                )
                - self.initial_amount
            )
            df_total_value.columns = ["account_value"]
            df_total_value["date"] = self.date_memory
            df_total_value["daily_return"] = df_total_value["account_value"].pct_change(
                1
            )
            if df_total_value["daily_return"].std() != 0:
                sharpe = (
                    (252 ** 0.5)
                    * df_total_value["daily_return"].mean()
                    / df_total_value["daily_return"].std()
                )
            df_rewards = pd.DataFrame(self.rewards_memory)
            df_rewards.columns = ["account_rewards"]
            df_rewards["date"] = self.date_memory[:-1]
            if self.episode % self.print_verbosity == 0:
                print(f"day: {self.day}, episode: {self.episode}")
                print(f"begin_total_asset: {self.asset_memory[0]:0.2f}")
                print(f"end_total_asset: {end_total_asset:0.2f}")
                print(f"total_reward: {tot_reward:0.2f}")
                print(f"total_cost: {self.cost:0.2f}")
                print(f"total_trades: {self.trades}")
                if df_total_value["daily_return"].std() != 0:
                    print(f"Sharpe: {sharpe:0.3f}")
                print("=================================")

            if (self.model_name != "") and (self.mode != ""):
                df_actions = self.save_action_memory()
                df_actions.to_csv(
                    "results/actions_{}_{}_{}.csv".format(
                        self.mode, self.model_name, self.iteration
                    )
                )
                df_total_value.to_csv(
                    "results/account_value_{}_{}_{}.csv".format(
                        self.mode, self.model_name, self.iteration
                    ),
                    index=False,
                )
                df_rewards.to_csv(
                    "results/account_rewards_{}_{}_{}.csv".format(
                        self.mode, self.model_name, self.iteration
                    ),
                    index=False,
                )
                plt.plot(self.asset_memory, "r")
                plt.savefig(
                    "results/account_value_{}_{}_{}.png".format(
                        self.mode, self.model_name, self.iteration
                    ),
                    index=False,
                )
                plt.close()

            return self.state, self.reward, self.terminal, {}

        else:
```

```
            actions = actions * self.hmax  # actions initially is scaled between 0 to 1
            actions = actions.astype(
                int
            )  # convert into integer because we can't by fraction of shares
            if self.turbulence_threshold is not None:
                if self.turbulence >= self.turbulence_threshold:
                    actions = np.array([-self.hmax] * self.stock_dim)
            begin_total_asset = self.state[0] + sum(
                np.array(self.state[1 : (self.stock_dim + 1)])
                * np.array(self.state[(self.stock_dim + 1) : (self.stock_dim * 2 + 1)])
            )

            argsort_actions = np.argsort(actions)

            sell_index = argsort_actions[: np.where(actions < 0)[0].shape[0]]
            buy_index = argsort_actions[::-1][: np.where(actions > 0)[0].shape[0]]

            for index in sell_index:
                actions[index] = self.stock_selling(index, actions[index]) * (-1)
            for index in buy_index:
                actions[index] = self.stock_buying(index, actions[index])

            self.actions_memory.append(actions)

            self.day += 1
            self.data = self.df.loc[self.day, :]
            if self.turbulence_threshold is not None:
                if len(self.df.tic.unique()) == 1:
                    self.turbulence = self.data[self.risk_indicator_col]
                elif len(self.df.tic.unique()) > 1:
                    self.turbulence = self.data[self.risk_indicator_col].values[0]
            self.state = self._update_state()

            end_total_asset = self.state[0] + sum(
                np.array(self.state[1 : (self.stock_dim + 1)])
                * np.array(self.state[(self.stock_dim + 1) : (self.stock_dim * 2 + 1)])
            )
            self.asset_memory.append(end_total_asset)
            self.date_memory.append(self._get_date())
            self.reward = end_total_asset - begin_total_asset
            self.rewards_memory.append(self.reward)
            self.reward = self.reward * self.rewards

        return self.state, self.reward, self.terminal, {}

    def reset(self):
        # initiate state
        self.state = self._initiate_state()

        if self.initial:
            self.asset_memory = [self.initial_amount]
        else:
            previous_total_asset = self.previous_state[0] + sum(
                np.array(self.state[1 : (self.stock_dim + 1)])
                * np.array(
                    self.previous_state[(self.stock_dim + 1) : (self.stock_dim * 2 + 1)]
                )
            )
            self.asset_memory = [previous_total_asset]

        self.day = 0
        self.data = self.df.loc[self.day, :]
        self.turbulence = 0
        self.cost = 0
        self.trades = 0
        self.terminal = False
        self.rewards_memory = []
        self.actions_memory = []
        self.date_memory = [self._get_date()]

        self.episode += 1

        return self.state

    def render(self, mode="human", close=False):
        return self.state
```

```
    def _initiate_state(self):
        if self.initial:
            # For Initial State
            if len(self.df.tic.unique()) > 1:
                # for multiple stock
                state = (
                    [self.initial_amount]
                    + self.data.close.values.tolist()
                    + [0] * self.stock_dim
                    + sum(
                        [
                            self.data[tech].values.tolist()
                            for tech in self.technical_indicators
                        ],
                        [],
                    )
                )
            else:
                # for single stock
                state = (
                    [self.initial_amount]
                    + [self.data.close]
                    + [0] * self.stock_dim
                    + sum([[self.data[tech]] for tech in self.technical_indicators], [])
                )
        else:
            # Using Previous State
            if len(self.df.tic.unique()) > 1:
                # for multiple stock
                state = (
                    [self.previous_state[0]]
                    + self.data.close.values.tolist()
                    + self.previous_state[
                        (self.stock_dim + 1) : (self.stock_dim * 2 + 1)
                    ]
                    + sum(
                        [
                            self.data[tech].values.tolist()
                            for tech in self.technical_indicators
                        ],
                        [],
                    )
                )
            else:
                # for single stock
                state = (
                    [self.previous_state[0]]
                    + [self.data.close]
                    + self.previous_state[
                        (self.stock_dim + 1) : (self.stock_dim * 2 + 1)
                    ]
                    + sum([[self.data[tech]] for tech in self.technical_indicators], [])
                )
        return state

    def _update_state(self):
        if len(self.df.tic.unique()) > 1:
            # for multiple stock
            state = (
                [self.state[0]]
                + self.data.close.values.tolist()
                + list(self.state[(self.stock_dim + 1) : (self.stock_dim * 2 + 1)])
                + sum(
                    [
                        self.data[tech].values.tolist()
                        for tech in self.technical_indicators
                    ],
                    [],
                )
            )

        else:
            # for single stock
            state = (
                [self.state[0]]
                + [self.data.close]
```

```
                + list(self.state[(self.stock_dim + 1) : (self.stock_dim * 2 + 1)])
                + sum([[self.data[tech]] for tech in self.technical_indicators], [])
            )
        return state

    def _get_date(self):
        if len(self.df.tic.unique()) > 1:
            date = self.data.date.unique()[0]
        else:
            date = self.data.date
        return date

    def save_asset_memory(self):
        date_list = self.date_memory
        asset_list = self.asset_memory
        df_account_value = pd.DataFrame(
            {"date": date_list, "account_value": asset_list}
        )
        return df_account_value

    def save_action_memory(self):
        if len(self.df.tic.unique()) > 1:
            # date and close price length must match actions length
            date_list = self.date_memory[:-1]
            df_date = pd.DataFrame(date_list)
            df_date.columns = ["date"]

            action_list = self.actions_memory
            df_actions = pd.DataFrame(action_list)
            df_actions.columns = self.data.tic.values
            df_actions.index = df_date.date
        else:
            date_list = self.date_memory[:-1]
            action_list = self.actions_memory
            df_actions = pd.DataFrame({"date": date_list, "actions": action_list})
        return df_actions

    def _seed(self, seed=None):
        self.np_random, seed = seeding.np_random(seed)
        return [seed]

    def get_sb_env(self):
        e = DummyVecEnv([lambda: self])
        obs = e.reset()
```

```
ratio_list = ['operating_margin','net_profit_margin','return_over_assests','return_on_equity','current_ratio','quick_ratio','cash_ratio','inv
                  'debt_ratio','debt_to_equity','PE', 'PB', 'Div_yield']

stock_dim = len(stock_training.tic.unique())
state_space = 1 + 2*stock_dim + len(ratio_list)*stock_dim
print(f"Stock Dimension: {stock_dim}, State Space: {state_space}")
```

```
Stock Dimension: 30, State Space: 511
```

```
# Parameters for the environment
env_kwargs = {
    "hmax": 100,
    "initial_amount": 1000000,
    "buy_cost": 0.001,
    "sell_cost": 0.001,
    "state_space": state_space,
    "stock_dim": stock_dim,
    "technical_indicators": ratio_list,
    "action_space": stock_dim,
    "rewards": 1e-4

}

#Establish the training environment using StockTradingEnv() class
e_train_gym = StockTrading(df = stock_training, **env_kwargs)


env_train, _ = e_train_gym.get_sb_env()
print(type(env_train))
```

```
<class 'stable_baselines3.common.vec_env.dummy_vec_env.DummyVecEnv'>
```

```
# Set up the agent using DRLAgent() class using the environment created in the previous part
agent = DRLAgent(env = env_train)

if_using_ddpg = True
if_using_ppo = False
if_using_a2c = False


agent = DRLAgent(env = env_train)
PPO_PARAMS = {
    "n_steps": 2048,
    "ent_coef": 0.01,
    "learning_rate": 0.00025,
    "batch_size": 128,
}
model_ppo = agent.get_model("ppo",model_kwargs = PPO_PARAMS)

if if_using_ppo:
  # set up logger
  tmp_path = RESULTS_DIR + '/ppo'
  new_logger_ppo = configure(tmp_path, ["stdout", "csv", "tensorboard"])
  # Set new logger
  model_ppo.set_logger(new_logger_ppo)
```

```
{'n_steps': 2048, 'ent_coef': 0.01, 'learning_rate': 0.00025, 'batch_size': 128}
Using cpu device
```

```
trained_ppo = agent.train_model(model=model_ppo,
                             tb_log_name='ppo',
                             total_timesteps=500) if if_using_ppo else None


agent = DRLAgent(env = env_train)
ddpg_model = agent.get_model("ddpg")

if if_using_ddpg:
  # set up logger
  tmp_path = RESULTS_DIR + '/ddpg'
  ddpg_new_logger = configure(tmp_path, ["stdout", "csv", "tensorboard"])
  # Set new logger
  ddpg_model.set_logger(ddpg_new_logger)
```

```
{'batch_size': 128, 'buffer_size': 50000, 'learning_rate': 0.001}
Using cpu device
Logging to results/ddpg
```

```
trained_ddpg_model = agent.train_model(model=ddpg_model,
                             tb_log_name='ddpg',
                             total_timesteps=500) if if_using_ddpg else None


agent = DRLAgent(env = env_train)
a2c_model = agent.get_model("a2c")

if if_using_a2c:
  # set up logger
  tmp_path = RESULTS_DIR + '/a2c'
  a2c_new_logger = configure(tmp_path, ["stdout", "csv", "tensorboard"])
  # Set new logger
  a2c_model.set_logger(a2c_new_logger)
```

```
{'n_steps': 5, 'ent_coef': 0.01, 'learning_rate': 0.0007}
Using cpu device
```

```
trained_a2c_model = agent.train_model(model=a2c_model,
                             tb_log_name='a2c',
                             total_timesteps=500) if if_using_a2c else None


stock_trade = data_split(stock_data_final, TEST_START_DATE, TEST_END_DATE)
e_trade_gym = StockTrading(df = stock_training, **env_kwargs)


df.head()
```

	date	open	high	low	close	volume	tic	day
0	2000-01-03	0.936384	1.004464	0.907924	0.851942	535796800	AAPL	0
1	2000-01-03	70.000000	70.000000	62.875000	47.178246	22914900	AMGN	0
2	2000-01-03	47.995617	47.995617	45.515598	33.552006	6471267	AXP	0
3	2000-01-03	41.437500	41.687500	39.812500	25.940281	2638200	BA	0

```
df_account_value_ppo, df_actions_ppo = DRLAgent.DRL_prediction(
    model=trained_ppo,
    environment = e_trade_gym) if if_using_ppo else [None, None]

df_account_value_ddpg, df_actions_ddpg = DRLAgent.DRL_prediction(
    model=trained_ddpg_model,
    environment = e_trade_gym) if if_using_ddpg else [None, None]

df_account_value_a2c, df_actions_a2c = DRLAgent.DRL_prediction(
    model=trained_a2c_model,
    environment = e_trade_gym) if if_using_a2c else [None, None]
```

```
 hit end!
```

```
print("==============Get Backtest Results===========")
now = datetime.datetime.now().strftime('%Y%m%d-%Hh%M')

if if_using_ppo:
  print("\n ppo:")
  perf_stats_all_ppo = backtest_stats(account_value=df_account_value_ppo)
  perf_stats_all_ppo = pd.DataFrame(perf_stats_all_ppo)
  perf_stats_all_ppo.to_csv("./"+config.RESULTS_DIR+"/perf_stats_all_ppo_"+now+'.csv')

if if_using_ddpg:
  print("\n ddpg:")
  perf_stats_all_ddpg = backtest_stats(account_value=df_account_value_ddpg)
  perf_stats_all_ddpg = pd.DataFrame(perf_stats_all_ddpg)
  perf_stats_all_ddpg.to_csv("./"+config.RESULTS_DIR+"/perf_stats_all_ddpg_"+now+'.csv')

if if_using_a2c:
  print("\n a2c:")
  perf_stats_all_a2c = backtest_stats(account_value=df_account_value_a2c)
  perf_stats_all_a2c = pd.DataFrame(perf_stats_all_a2c)
  perf_stats_all_a2c.to_csv("./"+config.RESULTS_DIR+"/perf_stats_all_a2c_"+now+'.csv')
```

```
==============Get Backtest Results===========

 ddpg:
Annual return          0.052122
Cumulative returns     3.049730
Annual volatility      0.147950
Sharpe ratio           0.417405
Calmar ratio           0.122080
Stability              0.868694
Max drawdown          -0.426946
Omega ratio            1.097666
Sortino ratio          0.597895
Skew                        NaN
Kurtosis                    NaN
Tail ratio             0.971227
Daily value at risk   -0.018395
dtype: float64
```

```
print("==============Get Baseline Stats===========")
baseline_df = get_baseline(
        ticker="^DJI",
        start = TEST_START_DATE,
        end = TEST_END_DATE)

stats = backtest_stats(baseline_df, value_col_name = 'close')
```

```
==============Get Baseline Stats===========
[**********100%**********]  1 of 1 completed
Shape of DataFrame:  (756, 8)
Annual return          0.159544
Cumulative returns     0.559055
Annual volatility      0.235482
Sharpe ratio           0.748199
Calmar ratio           0.430198
```

```
Stability              0.680674
Max drawdown          -0.370862
Omega ratio            1.177415
Sortino ratio          1.035264
Skew                        NaN
Kurtosis                    NaN
Tail ratio             0.944436
Daily value at risk   -0.028969
dtype: float64
```

```
print("==============Compare to DJIA===========")
%matplotlib inline
# S&P 500: ^GSPC
# Dow Jones Index: ^DJI
# NASDAQ 100: ^NDX

if if_using_ppo:
  backtest_plot(df_account_value_ppo,
              baseline_ticker = '^DJI',
              baseline_start = TEST_START_DATE,
              baseline_end = TEST_END_DATE)
```

```
    ==============Compare to DJIA===========
```

```
if if_using_ddpg:
  backtest_plot(df_account_value_ddpg,
              baseline_ticker = '^DJI',
              baseline_start = TEST_START_DATE,
              baseline_end = TEST_END_DATE)
```

```
[**********100%**********]  1 of 1 completed
Shape of DataFrame:  (756, 8)
/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1448: RuntimeWarning:

Mean of empty slice

/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1450: RuntimeWarning:

Mean of empty slice

/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1457: RuntimeWarning:

Mean of empty slice

/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1291: RuntimeWarning:

Mean of empty slice
```

Start date	2000-01-03
End date	2018-12-30
Total months	330

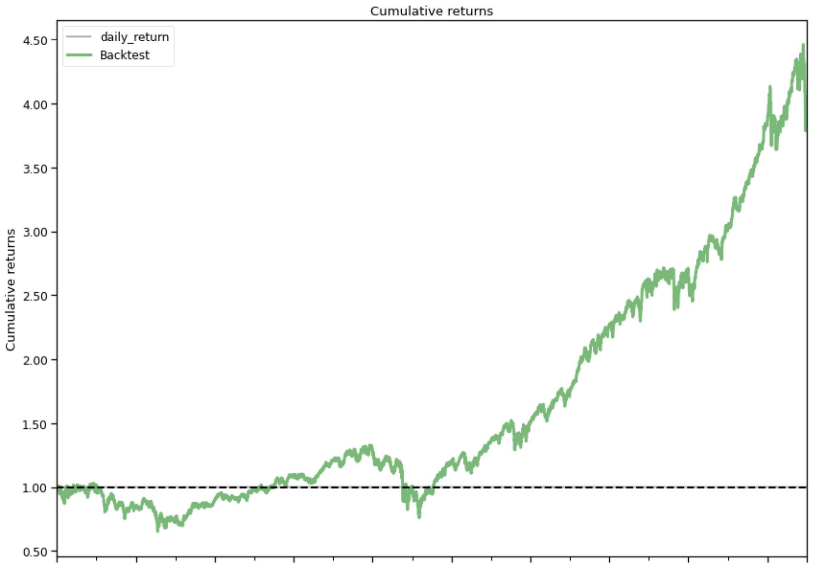
	Backtest
Annual return	5.212%
Cumulative returns	304.973%
Annual volatility	14.795%
Sharpe ratio	0.42
Calmar ratio	0.12
Stability	0.87
Max drawdown	-42.695%
Omega ratio	1.10
Sortino ratio	0.60
Skew	NaN
Kurtosis	NaN
Tail ratio	0.97
Daily value at risk	-1.839%
Alpha	NaN
Beta	NaN

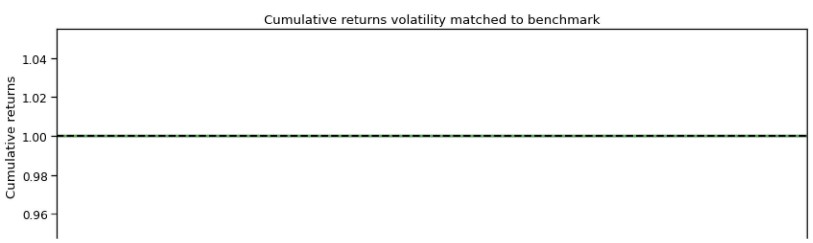
Worst drawdown periods	Net drawdown in %	Peak date	Valley date	Recovery date	Duration
0	42.69	2007-12-10	2009-03-07	2010-12-02	779
1	36.69	2000-11-29	2002-07-23	2005-07-15	1208
2	15.21	2011-07-07	2011-08-10	2012-01-10	134
3	15.14	2018-12-03	2018-12-22	NaT	NaN
4	13.47	2000-01-14	2000-03-14	2000-06-02	101

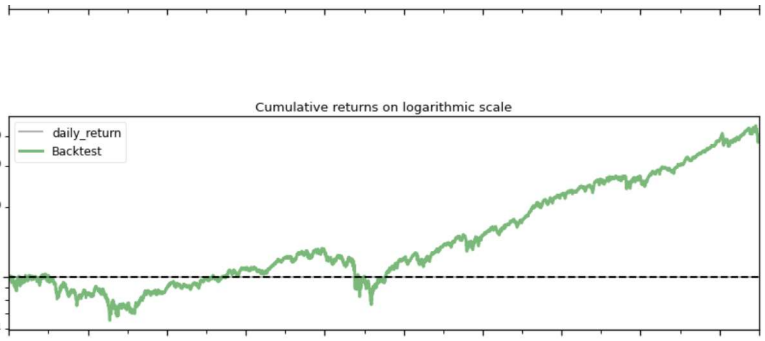
```
/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1448: RuntimeWarning:

Mean of empty slice

/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1450: RuntimeWarning:

Mean of empty slice

/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1457: RuntimeWarning:

Mean of empty slice

/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1448: RuntimeWarning:

Mean of empty slice
```

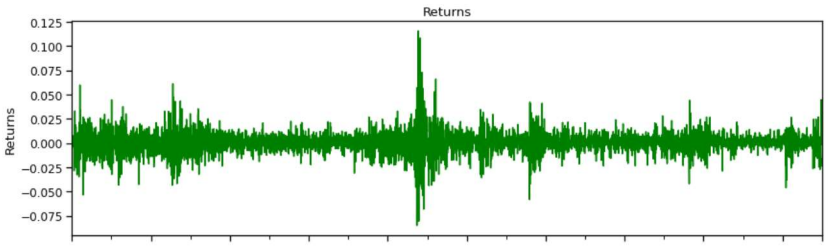
```
/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1450: RuntimeWarning:

Mean of empty slice

/usr/local/lib/python3.7/dist-packages/empyrical/stats.py:1457: RuntimeWarning:

Mean of empty slice
```

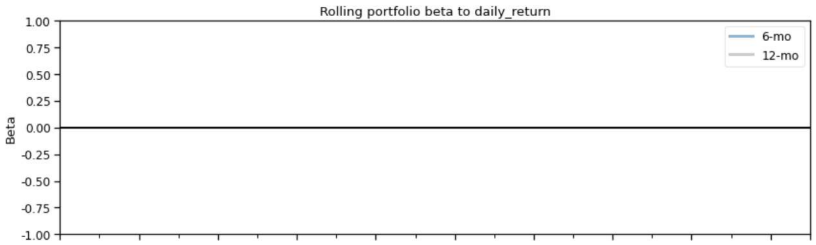
Stress Events	mean	min	max
Dotcom	0.06%	-5.36%	5.99%
Lehman	-0.03%	-8.51%	5.72%
9/11	-0.01%	-4.28%	1.98%
US downgrade/European Debt Crisis	0.04%	-5.83%	4.22%
Fukushima	0.10%	-1.78%	1.36%
US Housing	-0.22%	-2.81%	2.11%
EZB IR Event	0.06%	-0.75%	1.69%
Aug07	0.07%	-2.34%	2.27%
Mar08	0.05%	-2.23%	3.28%
Sept08	-0.13%	-8.51%	5.72%
2009Q1	-0.36%	-4.39%	2.82%
2009Q2	0.27%	-3.94%	6.59%
Flash Crash	-0.21%	-3.24%	3.45%
Apr14	-0.03%	-2.35%	1.32%
Oct14	0.13%	-2.13%	2.07%
Fall2015	-0.18%	-4.20%	4.41%
Low Volatility Bull Market	0.02%	-3.11%	2.68%
GFC Crash	-0.04%	-8.51%	11.57%
Recovery	0.05%	-5.83%	4.22%
New Normal	0.04%	-4.62%	4.46%

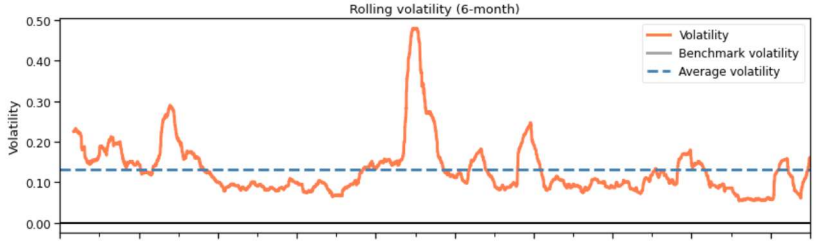


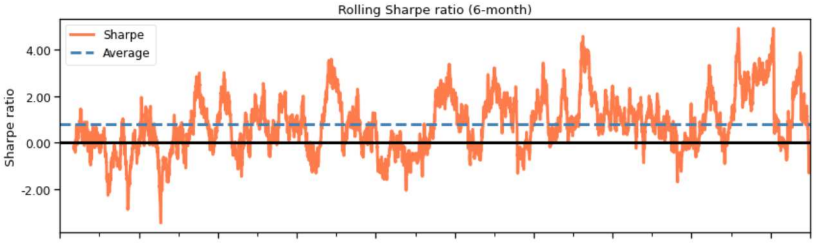


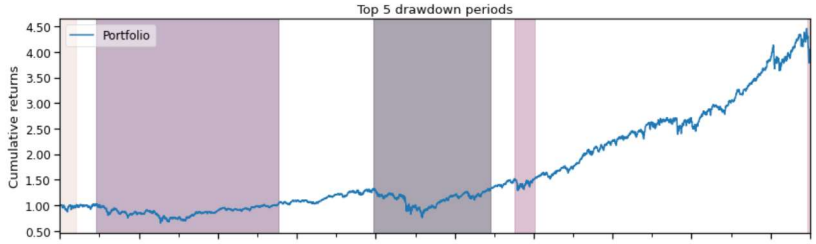

Cumulative returns on logarithmic scale
daily_return
Backtest
Cumulative returns

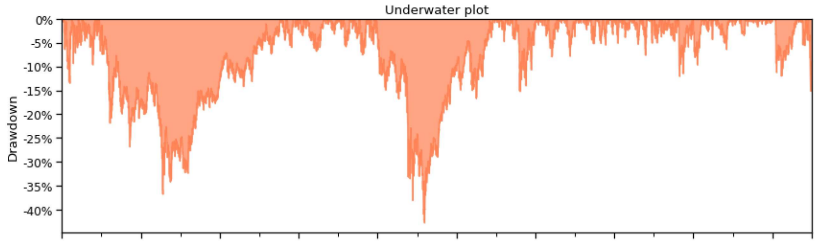

Returns
Returns

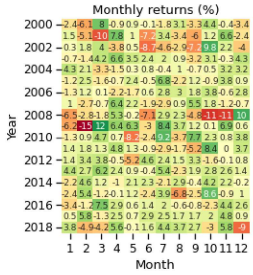

Rolling portfolio beta to daily_return
6-mo
12-mo
Beta

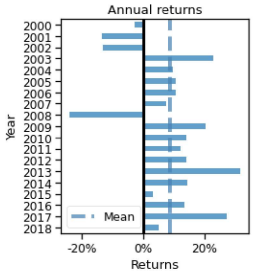

Rolling volatility (6-month)
Volatility
Benchmark volatility
Average volatility
Volatility

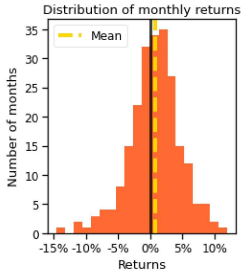

Rolling Sharpe ratio (6-month)
Sharpe
Average
Sharpe ratio

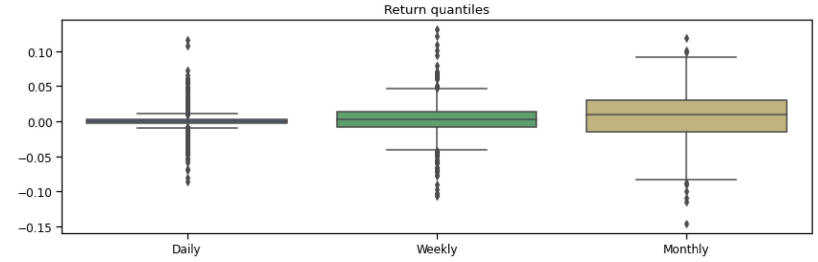

Top 5 drawdown periods
Portfolio
Cumulative returns

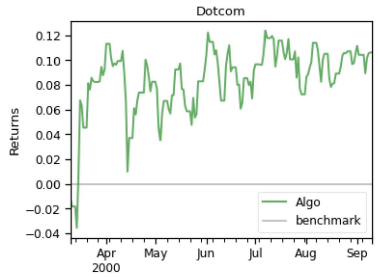

Underwater plot
Drawdown
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
-40%

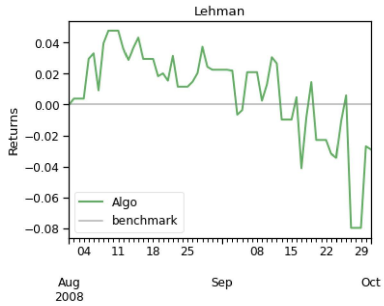

Monthly returns (%)
Year
Month
1 2 3 4 5 6 7 8 9 10 11 12

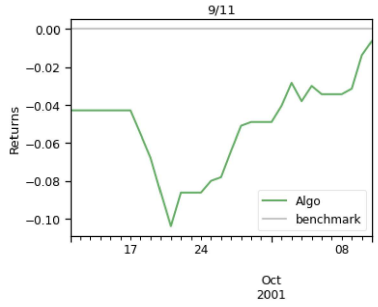

Annual returns
Year
Mean
-20%
0%
20%
Returns

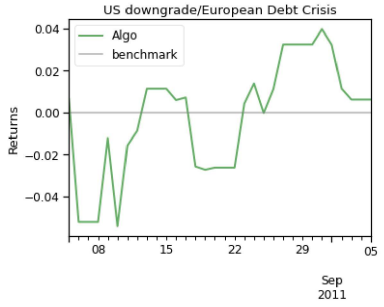

Distribution of monthly returns
Mean
Number of months
-15% -10% -5% 0% 5% 10%
Returns

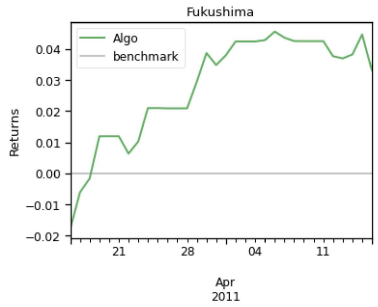

Return quantiles
Daily
Weekly
Monthly


Dotcom
Returns
Algo
benchmark
Apr
2000
May
Jun
Jul
Aug
Sep


Lehman
Returns
Algo
benchmark
Aug
2008
Sep
Oct

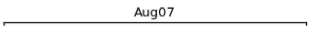

9/11
Returns
Algo
benchmark
Oct
2001

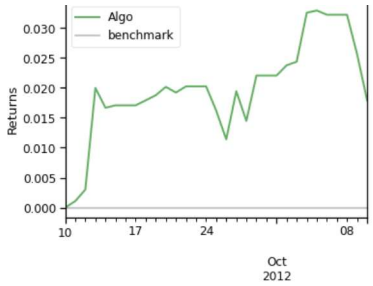

US downgrade/European Debt Crisis
Returns
Algo
benchmark
Sep
2011

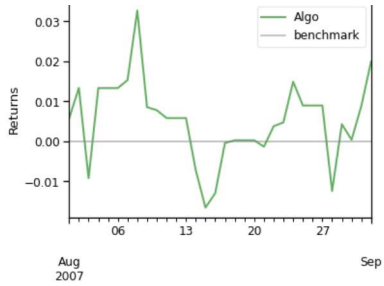

Fukushima
Returns
Algo
benchmark
Apr
2011

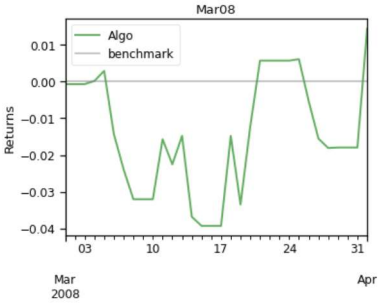

US Housing
Returns
Algo
benchmark
Feb
2003

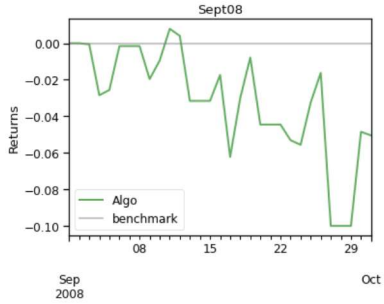

EZB IR Event

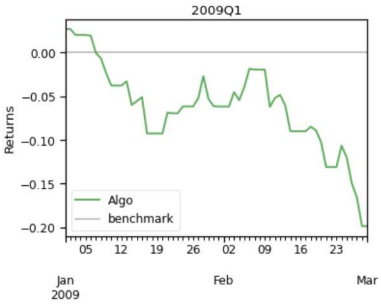

Aug07

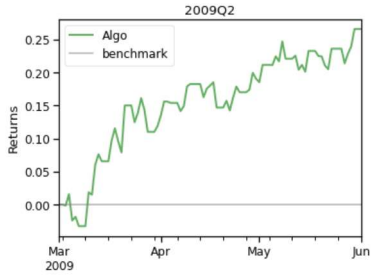

Algo
benchmark
Returns
Oct
2012

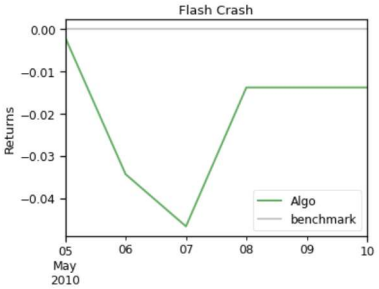

Algo
benchmark
Returns
Aug
2007
Sep

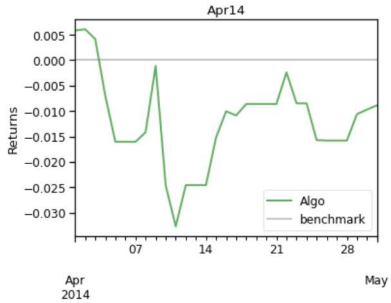

Mar08
Algo
benchmark
Returns
Mar
2008
Apr

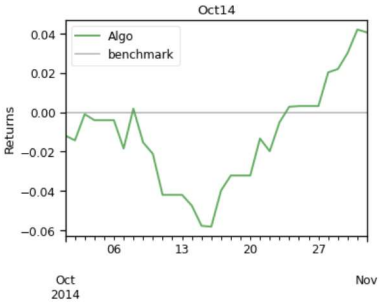

Sept08
Algo
benchmark
Returns
Sep
2008
Oct

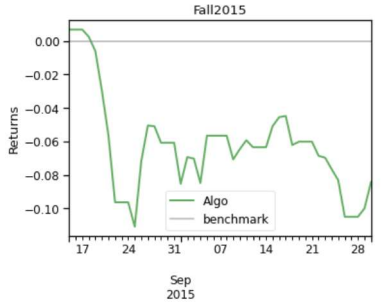

2009Q1
Algo
benchmark
Returns
Jan
2009
Feb
Mar

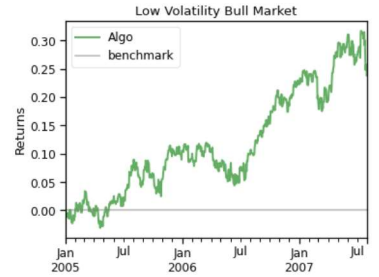

2009Q2
Algo
benchmark
Returns
Mar
2009
Apr
May
Jun

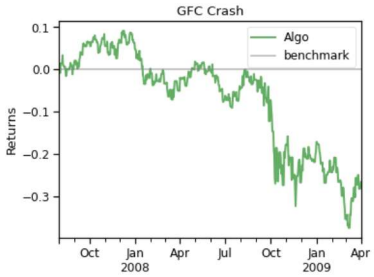

Flash Crash
Algo
benchmark
Returns
May
2010


Apr14
Algo
benchmark
Returns
Apr
2014
May


Oct14
Algo
benchmark
Returns
Oct
2014
Nov

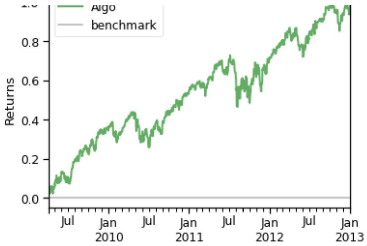

Fall2015
Algo
benchmark
Returns
Sep
2015

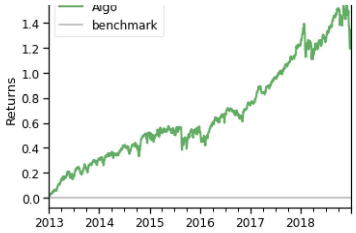

Low Volatility Bull Market
Algo
benchmark
Returns
Jan
2005
Jul
Jan
2006
Jul
Jan
2007
Jul


GFC Crash
Algo
benchmark
Returns
Oct
Jan
2008
Apr
Jul
Oct
Jan
2009
Apr


Recovery


New Normal






```
if if_using_a2c:
  backtest_plot(df_account_value_a2c,
              baseline_ticker = '^DJI',
              baseline_start = TEST_START_DATE,
              baseline_end = TEST_END_DATE)
```