Cryptocurrencies Price Prediction using a RNN

Abstract

An investment in bitcoin is the equivalent of betting on the increased adoption of this asset. Contrary to the US dollar, which used to be backed by gold and currently is backed by trust on the US government) bitcoin itself has no intrinsic value. This means that bitcoin's market price is based on the law of supply and demand. Furthermore, bitcoin has a cap on the amount of coins produced, namely 21 million. This makes bitcoin a deflationary asset, which translates into a greater economic value as its supply decreases. This project uses machine learning to test if bitcoin's market price can be significantly predicted by other Bitcoin's blockchain features such as market price, hash rate, difficulty adjustment, transactions volume... A RNN (Recurrent Neural Network) will be used to predict a time-series dataset.

Goal

- Use a RNN to predict against a time-series dataset of 4 cryptocurrencies: BTC, LTC, ETH, BCH
- The goal is that the neural network doesn't just memorize our data and that it instead "generalizes" and learns the actual problem and patterns associated with it.

Input data

- The data we'll be using is Open, High, Low, Close, Volume data for Bitcoin, Ethereum, Litecoin and Bitcoin Cash.
- Since there are different ways to measure the price (opening price, closing price, high price, low price...) we specify that the model uses the `Close` and `Volume` columns from the input dataset
- We're going to be tracking the `Close` and `Volume` every minute for Bitcoin, Litecoin, Ethereum, and Bitcoin Cash.

Install Libraries

In [1]:
```
!pip install sklearn tensorflow keras pandas numpy matplotlib;
```

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WARNING: You are using pip version 20.2.3; however, version 21.3.1 is available.
You should consider upgrading via the '/Users/alvaroserranorivas/.pyenv/versions/3.9.2/envs/bitcoin_linear_regression/bin/python3.9 -m pip install --upgrade pip' command.
```

Import Libraries

In [4]:

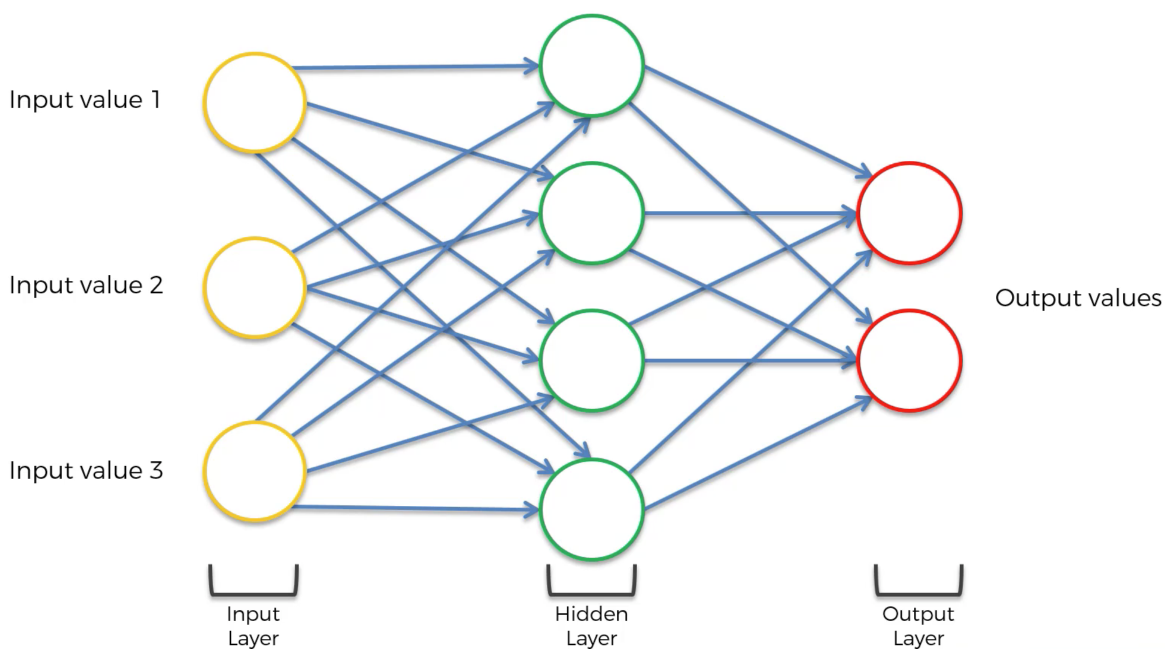
```python
# import libraries
import random
from collections import deque
from pathlib import Path
```

```
import time


import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import requests
from sklearn import preprocessing

# Keras libraries
from tensorflow.keras.models import Sequential
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.layers import LSTM, Dense, Dropout,
BatchNormalization
from tensorflow.keras.callbacks import TensorBoard,
ModelCheckpoint
```

Define constant variables

Key concepts:

- **Neural Network**:

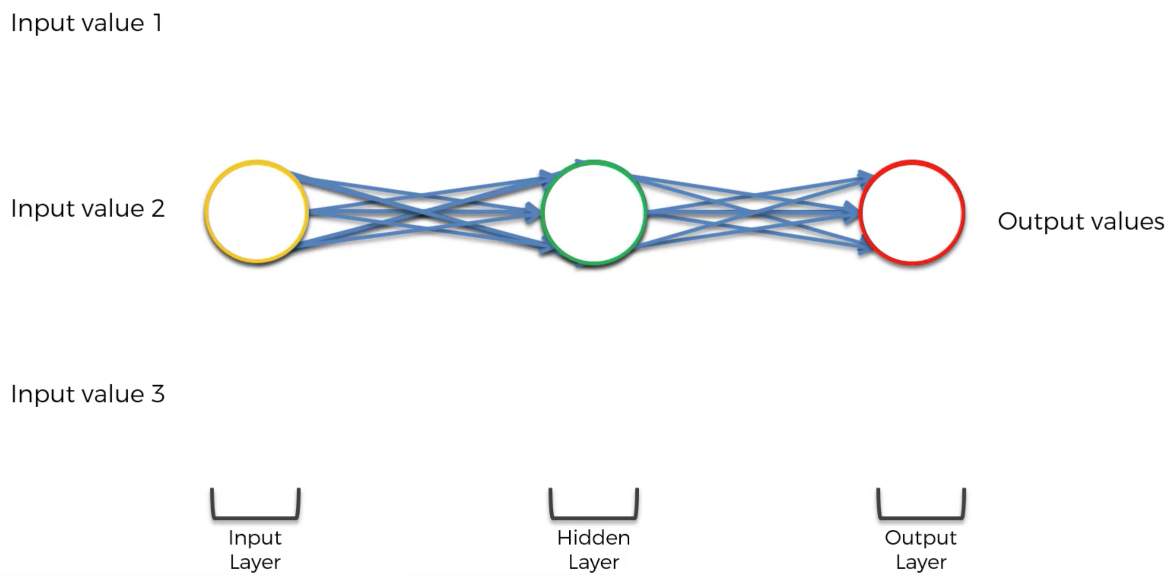


- **Batches**: Total number of training samples that are fed one-by-one to the Neural Network
- **Epoch**: One epoch is when the dataset has been passed forward and backward the RNN once. Therefore, the greater the number of epochs, the better the accuracy of the model. However, too many epochs could lead to overfitting

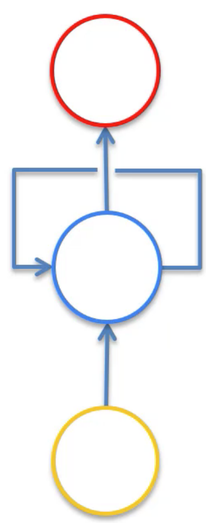
- **Overfitting**: The model memorizes its behavior and therefore, it will perform on the training data but it will do poorly on the test or validation data.

How to build a RNN from a Feed-Forward Neural Network

1. Squash layers together:

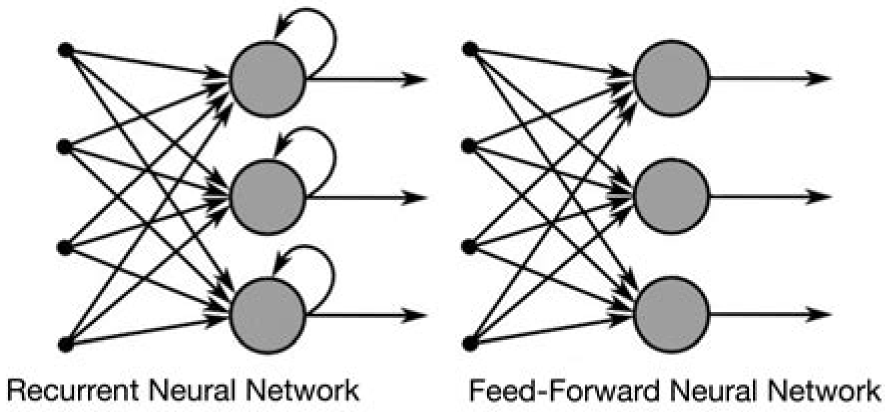


2. Simplify synapses of the neuron to a single line
3. Rotate by 90 degrees
4. Generate a loop around the hidden layer of the neural network



How are RNN different?

The hidden layer used on a specific observation a dataset is not only used to generate output for that observation, but it is also used to train the hidden layer of the next observation.



Why do we need a RNN to solve this buying/selling decision problem?

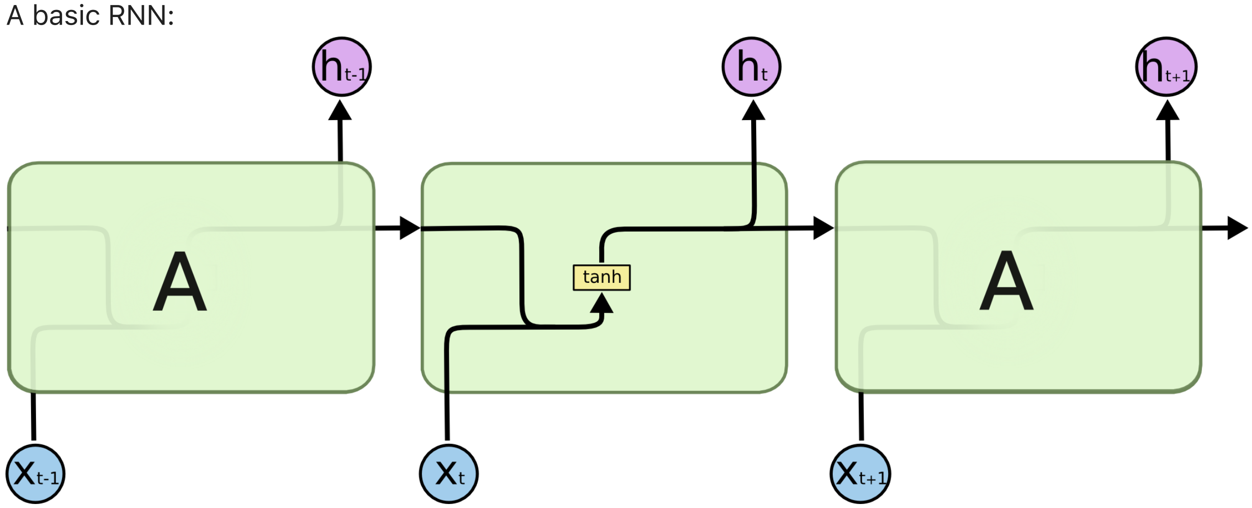
- It allows us to update the hidden state in a deterministic nonlinear way
    - We send the chose price back to the network as an input
- RNNs hold a distributed hidden state that allows them to store a lot of information about the pat efficiently
- RNNs nonlinear dynamics allow them to update their hidden state in a deterministic way where thre is no need to infer the hidden state.

Time complexity

Since the hidden layer of one observation is used to train the hidden layer of the next observation, the gradient descent algortihm is then combined with a backpropagation algorithm. Therefore, the cost fnuction of the neural network is calculated for each observation in the dataset

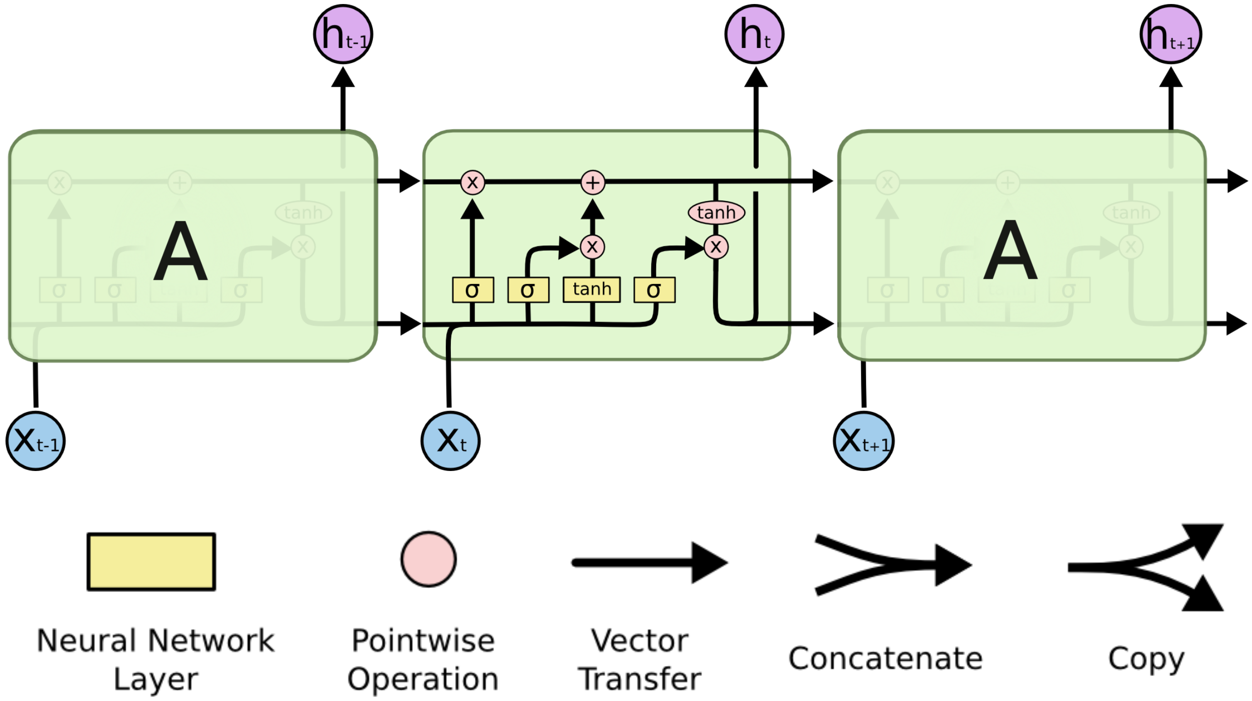
LSTM

A basic RNN:

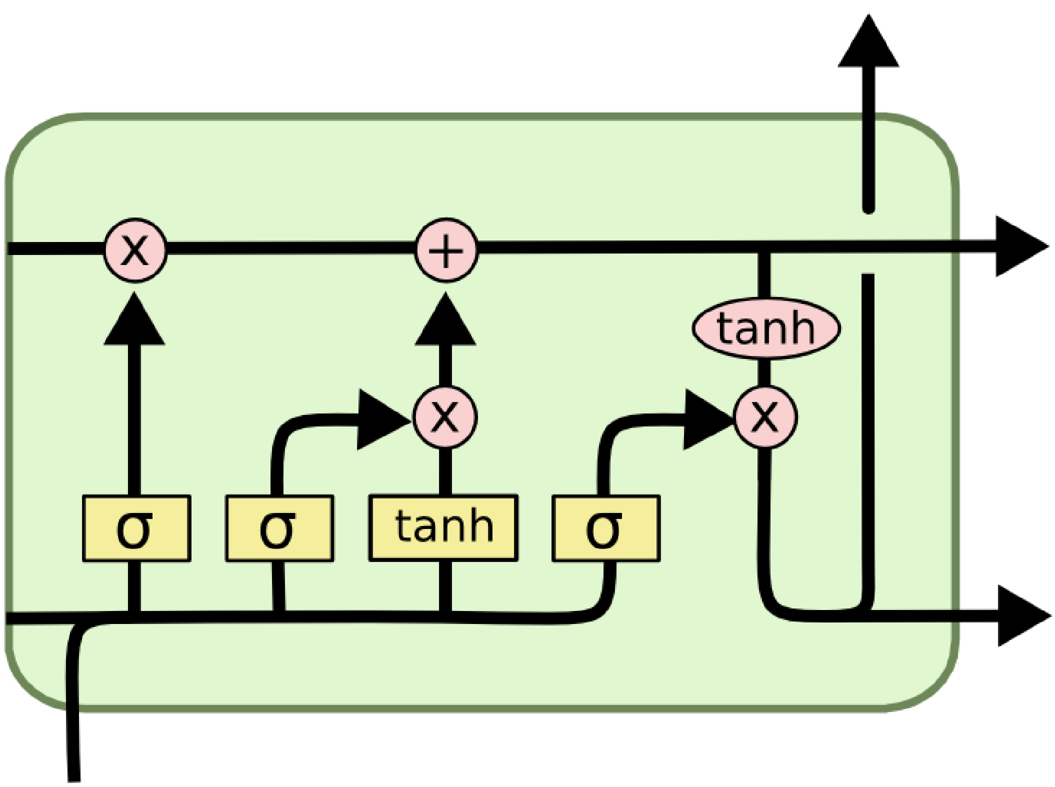


This neural network has neurons and synapses that transmit the weighted sums of the outputs from one layer as the inputs of the next layer. A backpropagation algorithm will move backwards through this algorithm and update the weights of each neuron in response to he cost function computed at each epoch of its training stage.

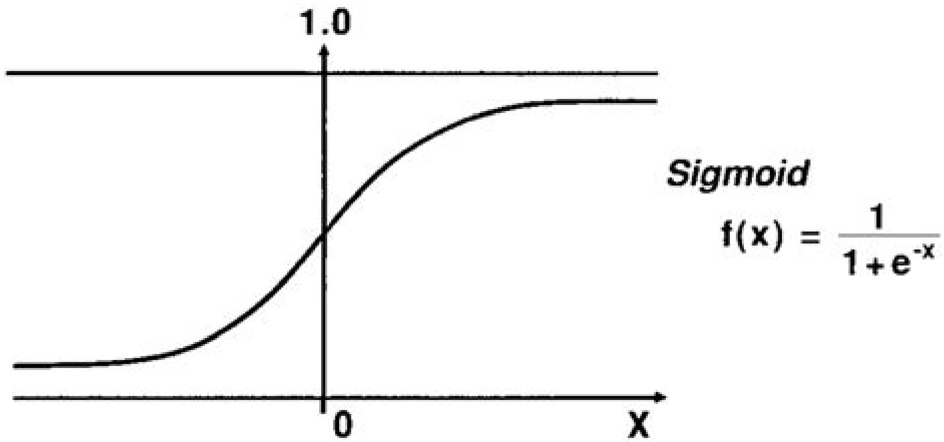
LSTM applied to a Deep Learning Problem



Appearance of each layer in the LSTM RNN



Activation function: Sigmoid function

The 

is used as a type of activation function in LSTMs that determines what information is passed through a gate to affect the network’s cell state.

- Loss is a calculation of error:
  - a RNN does not attempt to maximize accuracy
  - a RNN's goal is to minimize loss

In [5]:
```
PRECEDING_PRICES = 60
FUTURE_PRICES_PREDICT = 3
EPOCHS = 10  # how many times to train the model
BATCH_SIZE = 64  # how many samples per batch
TO_PREDICT = "BTC-USD"
NAME = f"{TO_PREDICT}-{PRECEDING_PRICES}-SEQ-
{FUTURE_PRICES_PREDICT}-PRED-{int(time.time())}"
```

The process of building a RNN

Input Data: Combine price and volume for each coin into a single feature

In [4]:
```
main_df = pd.DataFrame()

data_directory: Path = Path("./crypto-data")

for file in data_directory.glob("*.csv"):
    file_name = file.name.split(".")[0]
    df = pd.read_csv(f"{data_directory.name}/{file.name}",
names = ["time", "low", "high", "open", "close", "volume"],
encoding="ISO-8859-1")
    df.rename(columns={"close": f"{file_name}_close", "volume":
f"{file_name}_volume"}, inplace=True)
```

```
    df.set_index("time", inplace=True)
    df = df[[f"{file_name}_close", f"{file_name}_volume"]]
    df.dropna(inplace=True)
    main_df = df if len(main_df) == 0 else main_df.join(df)

main_df.fillna(method="ffill", inplace=True)
main_df.dropna(inplace=True)
print(main_df.head())
```

```
            ETH-USD_close  ETH-USD_volume  BTC-USD_close  BTC-USD_volume  \
time
1528968720      486.01001       26.019083    6487.379883        7.706374
1528968780      486.00000        8.449400    6479.410156        3.088252
1528968840      485.75000       26.994646    6479.410156        1.404100
1528968900      486.00000       77.355759    6479.979980        0.753000
1528968960      486.00000        7.503300    6480.000000        1.490900

            BCH-USD_close  BCH-USD_volume  LTC-USD_close  LTC-USD_volume
time
1528968720     870.859985       26.856577      96.660004      314.387024
1528968780     870.099976        1.124300      96.570000       77.129799
1528968840     870.789978        1.749862      96.500000        7.216067
1528968900     870.000000        1.680500      96.389999      524.539978
1528968960     869.989990        1.669014      96.519997       16.991997
```

Define logic for making a decision (Buy/Sell)

- If the "future" column is higher, we buy.
- Else,we sell

In [5]:

```
def make_order_decision(current_price, future_price):
        if float(current_price) < float(future_price):
                return 1 # buy order
        else:
                return 0
```

Speculate future price based on closing prices from the past

Choose target:

- Price we are trying to predict
- How far out in the future we are trying to predict

In [6]:

```
main_df["future_price_to_predict"] = main_df[f"{TO_PREDICT}_close"].shift(-FUTURE_PRICES_PREDICT) # negative to shift columnn up
```

```
main_df["order_decision"] = list(map(make_order_decision,
main_df[f"{TO_PREDICT}_close"],
main_df["future_price_to_predict"]))
main_df.dropna(inplace=True)
```

Prediction:

Will price rise or fall?

Should I buy or should I sell?

Apply feature scaling to the dataset

There are 2 alternatives:

- Standardization
- Normalization

Since our output is trying to predict whether price will fall or rise for each cryptocurrencies:

1. Take the price of all assets
2. Pick a target and take its future price
3. Choose a time frame step: how many observations should be considered when the RNN makes a prediction about the current observation.
4. Make a decision about the classification function we will be using (how are we going to predict the price): a) Make it a regression question: using a linear activation with output lyer b) Use **binary classification** (we pick this one)

1. **Balance** the buys and sells: make sure that there are the same number of examples for each cryptocurrency (same number of recorded transactions for each coin)

- a) Feed weights to the model to measure error accordingly
- b) Trim down datasets to make them all have approximately the same number of transactions recorded
- Not balancing could lead to a our model to predict only one coin, whichever is the most common, and memorize it ##### 2. Scale and normalize the data
- The order_decision column is not normalized

Data validation, and sequence normalization

1. Split training and test datasets:

- Since the data is inherently sequential, taking sequeneces that do not come in the future is likely a mistake.

1. Validate the data:

- Sequences that are, for example, 1 minute apart, are likely to be the same, thus indicating an identical Buy or Sell signal. This might cause the model to be overfitted on the test split.

In order to remediate this, the validation data is sliced while it is still in order

1. Create random sequences and shuffle them before balancing

In [7]:

```
def normalize_and_scale_df(df):
        df = df.drop("future_price_to_predict", axis=1)
        for column in df.columns:
                if column != "order_decision":
                        df[column] = df[column].pct_change()
                        df.dropna(inplace=True)
                        df[column] = 
preprocessing.scale(df[column].values)
        df.dropna(inplace=True)
        predictions_sequence = []
        previous_days_sequence = deque(maxlen=PRECEDING_PRICES)
        for value in df.values:
                previous_days_sequence.append([i for i in 
value[:-1]])
                if len(previous_days_sequence) == 
PRECEDING_PRICES:
                        
predictions_sequence.append([np.array(previous_days_sequence), 
value[-1]])
        random.shuffle(predictions_sequence)
        buy_orders = []
        not_buy_orders = []
        for sequence, order_decision in predictions_sequence:
                if order_decision == 1:
                        buy_orders.append([sequence, 
order_decision])
                else:
                        not_buy_orders.append([sequence, 
order_decision])
        random.shuffle(buy_orders)
        random.shuffle(not_buy_orders)
        shorter_sequence = min(len(buy_orders), 
len(not_buy_orders))
```

```
        buy_orders = buy_orders[:shorter_sequence]
        not_buy_orders = not_buy_orders[:shorter_sequence]
        predictions_sequence = buy_orders + not_buy_orders
        random.shuffle(predictions_sequence)
        x_data = []
        y_data = []
        for sequence, order_decision in predictions_sequence:
                x_data.append(sequence)
                y_data.append(order_decision)
        return np.array(x_data), y_data
```

In [8]:

```
sorted_dates = sorted(main_df.index.values)
last_5_percent = sorted(main_df.index.values)[-
int(len(sorted_dates) * 0.05)]
test_df = main_df[(main_df.index >= last_5_percent)]
print(f"Shape of test data: {test_df.shape}")
main_df = main_df[(main_df.index < last_5_percent)]
print(f"Shape of training data: {main_df.shape}")
# x_train is a numpy array of sequences
# y_train is a list of buy or not to buy (1 or 0)
x_train, y_train = normalize_and_scale_df(main_df)
x_test, y_test = normalize_and_scale_df(test_df)
print(test_df.head())

print(f"train data: {len(x_train)} test data: {len(x_test)}")
print(f"Train Dont buys: {y_train.count(0)}, buys:
{y_train.count(1)}")
print(f"Test Dont buys: {y_test.count(0)}, buys:
{y_test.count(1)}")
```

```
Shape of test data: (5141, 10)
Shape of training data: (97687, 10)
            ETH-USD_close  ETH-USD_volume  BTC-USD_close  BTC-USD_volume  \
time
1534904940     291.140015        6.290395    6705.200195        8.163854
1534905000     291.570007      489.621918    6700.000000        9.827062
1534905060     292.299988      173.859314    6700.000000       13.631424
1534905120     292.399994       77.035606    6702.359863       12.383007
1534905180     292.600006       89.692940    6711.560059       15.645502
```

```
            BCH-USD_close  BCH-USD_volume  LTC-USD_close  LTC-USD_volume  \
time
1534904940     559.989990        5.615524      58.220001      135.698441
1534905000     558.239990       35.015507      57.930000      864.464905
1534905060     560.640015       84.553719      58.250000      563.237671
1534905120     560.229980      101.587196      58.439999      422.931000
1534905180     560.979980       53.466728      58.450001       23.478930

            future_price_to_predict  order_decision
time
1534904940              6702.359863               0
1534905000              6711.560059               1
1534905060              6710.000000               1
1534905120              6701.379883               0
1534905180              6704.790039               0
train data: 82722 test data: 4726
Train Dont buys: 41361, buys: 41361
Test Dont buys: 2363, buys: 2363
```

Build and train the model

Building the model

1. Initialize a Sequential Model
2. Add the first LSTM layer: 2.1 Number of neurons to include in the first layer 2.2 `return_sequences` must be set to True so that we can add more layers to the model. 2.3 Specify the number of timesteps and predictors to use: `closing price` and `volume` 2.4 Add a Dropout Reguralization function to keep the same number of neurons while we add 3 more LSTM layers to the model 2.5 set `return_sequences` to False for the last layer 2.6 Add the output layer to the RNN as an instance of the Dense class.

In [9]:
```
model = Sequential()
model.add(LSTM(128, input_shape=(x_train.shape[1:]),
return_sequences=True))
model.add(Dropout(0.2))
model.add(BatchNormalization())

model.add(LSTM(128, return_sequences=True))
model.add(Dropout(0.1))
model.add(BatchNormalization())

model.add(LSTM(128))
model.add(Dropout(0.2))
model.add(BatchNormalization())
```

```
model.add(Dense(32, activation='relu'))
model.add(Dropout(0.2))

model.add(Dense(2, activation='softmax'))
```

```
2021-11-16 16:46:25.430608: I tensorflow/core/platform/cpu_feature_guard.cc:151]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library (one
DNN) to use the following CPU instructions in performance-critical operations:
AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate comp
iler flags.
```

Model Compilation Settings: Adam Optimizier

1. Use Adam Optmizer
2. Specify the loss function: we use the mean squared error because we are dealing with a continuous variable

In [10]:

```
opt = Adam(learning_rate=0.001, decay=1e-6)

# Compile model
model.compile(
    loss='sparse_categorical_crossentropy',
    optimizer=opt,
    metrics=['accuracy']
)
tensorboard = TensorBoard(log_dir="logs/{}".format(NAME))
```

Model Checkpoint

In [11]:

```
model_checkpoint = "RNN_Final-{epoch:02d}-{val_accuracy:.3f}"
checkpoint =
ModelCheckpoint("models/{}.model".format(model_checkpoint,
monitor='val_accuracy', verbose=1, save_best_only=True,
mode='max'))
```

Traning the model

In [12]:

```
history = model.fit(
    x_train, np.array(y_train),
    batch_size=BATCH_SIZE,
```

```
    epochs=EPOCHS,
    validation_data=(x_test, np.array(y_test)),
    callbacks=[tensorboard, checkpoint],
)
```

```
Epoch 1/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6930 - accuracy:
0.5472
```

```
2021-11-16 16:49:47.925878: W tensorflow/python/util/util.cc:368] Sets are not c
urrently considered sequences, but this may change in the future, so consider av
oiding using them.
WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-01-0.531.model/assets
```

```
INFO:tensorflow:Assets written to: models/RNN_Final-01-0.531.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 209s 157ms/step - loss: 0.6930 - ac
curacy: 0.5472 - val_loss: 0.6893 - val_accuracy: 0.5307
Epoch 2/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6505 - accuracy:
0.5849
```

```
WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-02-0.575.model/assets
```

```
INFO:tensorflow:Assets written to: models/RNN_Final-02-0.575.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
```

```
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 242s 187ms/step - loss: 0.6505 - ac
curacy: 0.5849 - val_loss: 0.6868 - val_accuracy: 0.5753
Epoch 3/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6453 - accuracy:
0.5979
WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-03-0.574.model/assets
INFO:tensorflow:Assets written to: models/RNN_Final-03-0.574.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 241s 186ms/step - loss: 0.6453 - ac
curacy: 0.5979 - val_loss: 0.6734 - val_accuracy: 0.5743
Epoch 4/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6425 - accuracy:
0.6029
WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-04-0.573.model/assets
INFO:tensorflow:Assets written to: models/RNN_Final-04-0.573.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
```

```
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 231s 179ms/step - loss: 0.6425 - ac
curacy: 0.6029 - val_loss: 0.6758 - val_accuracy: 0.5728
Epoch 5/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6402 - accuracy:
0.6060
```

```
WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-05-0.579.model/assets
```

```
INFO:tensorflow:Assets written to: models/RNN_Final-05-0.579.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 215s 166ms/step - loss: 0.6402 - ac
curacy: 0.6060 - val_loss: 0.6716 - val_accuracy: 0.5791
Epoch 6/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6383 - accuracy:
0.6114
```

```
WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-06-0.573.model/assets
```

```
INFO:tensorflow:Assets written to: models/RNN_Final-06-0.573.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
```

```
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 267s 206ms/step - loss: 0.6383 - ac
curacy: 0.6114 - val_loss: 0.6787 - val_accuracy: 0.5734
Epoch 7/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6376 - accuracy:
0.6132

WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-07-0.579.model/assets

INFO:tensorflow:Assets written to: models/RNN_Final-07-0.579.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 197s 152ms/step - loss: 0.6376 - ac
curacy: 0.6132 - val_loss: 0.6728 - val_accuracy: 0.5791
Epoch 8/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6322 - accuracy:
0.6203

WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-08-0.572.model/assets

INFO:tensorflow:Assets written to: models/RNN_Final-08-0.572.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
```

```
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 195s 151ms/step - loss: 0.6322 - ac
curacy: 0.6203 - val_loss: 0.6768 - val_accuracy: 0.5715
Epoch 9/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6285 - accuracy:
0.6270

WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-09-0.570.model/assets

INFO:tensorflow:Assets written to: models/RNN_Final-09-0.570.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 196s 152ms/step - loss: 0.6285 - ac
curacy: 0.6270 - val_loss: 0.6815 - val_accuracy: 0.5702
Epoch 10/10
1293/1293 [==============================] - ETA: 0s - loss: 0.6228 - accuracy:
0.6324

WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/RNN_Final-10-0.553.model/assets

INFO:tensorflow:Assets written to: models/RNN_Final-10-0.553.model/assets
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
```

```
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
1293/1293 [==============================] - 233s 180ms/step - loss: 0.6228 - ac
curacy: 0.6324 - val_loss: 0.6939 - val_accuracy: 0.5529
```

Save Model Score

In [13]:

```
model_score = model.evaluate(x_test, np.array(y_test),
verbose=0)
print('Test loss:', model_score[0])
print('Test accuracy:', model_score[1])
model.save("models/{}".format(NAME))
```

```
Test loss: 0.6938707232475281
Test accuracy: 0.5528988838195801
```

```
WARNING:absl:Found untraced functions such as lstm_cell_layer_call_fn, lstm_cell
_layer_call_and_return_conditional_losses, lstm_cell_1_layer_call_fn, lstm_cell_
1_layer_call_and_return_conditional_losses, lstm_cell_2_layer_call_fn while savi
ng (showing 5 of 15). These functions will not be directly callable after loadin
g.
INFO:tensorflow:Assets written to: models/BTC-USD-60-SEQ-3-PRED-1637099178/asset
s
```

```
INFO:tensorflow:Assets written to: models/BTC-USD-60-SEQ-3-PRED-1637099178/asset
s
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x157f16490> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15858d640> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.LSTMCell object at 0x15863e610> has the sam
e name 'LSTMCell' as a built-in Keras object. Consider renaming <class 'keras.la
yers.recurrent.LSTMCell'> to avoid naming conflicts when loading with `tf.keras.
models.load_model`. If renaming is not possible, pass the object in the `custom_
objects` parameter of the load function.
```

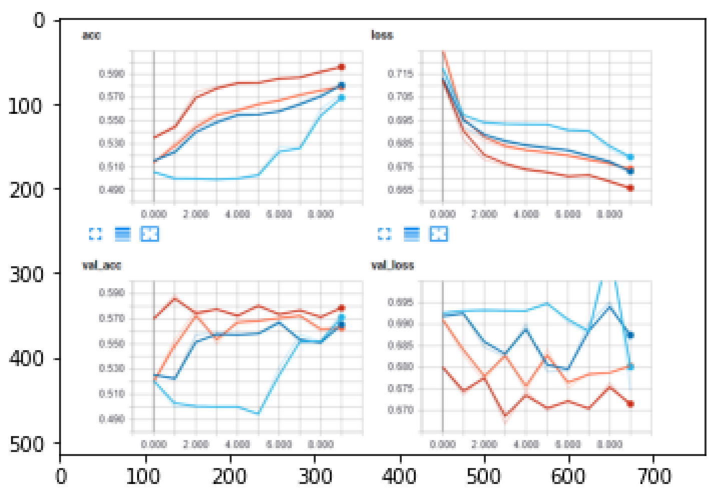
In [14]:
```
!tensorboard --logdir=logs
```

```
NOTE: Using experimental fast data loading logic. To disable, pass
    "--load_fast=false" and report issues on GitHub. More details:
    https://github.com/tensorflow/tensorboard/issues/4784

Serving TensorBoard on localhost; to expose to the network, use a proxy or pass
--bind_all
TensorBoard 2.7.0 at http://localhost:6006/ (Press CTRL+C to quit)
```

Tensorboard Dashboard Results

- Red: BCH-USD
- Light Blue: BTC-USD
- Dark Blue: ETH-USD
- Orange: LTC-USD

In [2]:
```
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
image = mpimg.imread("tensorboard-dashboard.png")
plt.imshow(image)
plt.show()
```



Conclusion

After we fit the model we notice that, as we train it, the loss goes down and, as a consequence, the accuracy goes up to 98%-99%

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