USING STATISTICAL MODEL AND MACHINE LEARNING FOR GOLD PRICE PREDICTION

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*Abstract*— This report presents a comparative analysis of three models, including Linear Regression, Gated Recurrent Unit (GRU), Autoregressive Integrated Moving Average (ARIMA), Long Short-Term Memory (LSTM) for predicting gold prices. The models are evaluated using MAE, MAPE, and RMSE metrics on historical gold price indicators data. The model with the lowest MAE, MAPE, and RMSE is recommended for gold price forecasting, contributing to improved understanding and accurate predictions in the gold market.

Keywords— gold price, forecasting, GRU, ARIMA, LSTM, gc=f, GLD, NEM…

# INTRODUCTION

The prices of gold trading symbols such as GC=F (Gold Futures), GLD (SPDR Gold Shares ETF), and NEM (Newmont Corporation) are significantly influenced by supply and demand dynamics, shaped by factors such as economic conditions, geopolitical uncertainties, inflation rates, and consumer preferences. Historically, gold and related assets have been viewed as safe-haven investments, particularly during periods of rising inflation, when investors seek to protect their wealth, leading to increased demand and higher prices. Conversely, during times of low inflation, demand for these assets may decline, causing prices to drop. Understanding these relationships is essential for identifying market trends and making informed investment decisions. This research focuses on evaluating the effectiveness of various statistical and machine learning models in predicting the future prices of GC=F, GLD, and NEM.

# RELATED WORK

Numerous studies have explored methods for predicting gold prices. For instance, Zhi Li [1] demonstrated the effectiveness of the random forest algorithm, incorporating factors such as the DJIA and S&P500. Shruti Garg [2] employed a Bayesian neural network, achieving a mean percentage error of just 1%. While primarily focused on temperature forecasting, Garima Jan [3] provided a comparison between ARIMA and Exponential Smoothing models. Alex Sherstinsky [4] offered an in-depth tutorial on LSTM networks. In Vietnam, Ho Thanh Tri et al. [5] applied the ARIMA(5,1,5) model to forecast gold prices, while Dan Liu and Xiaohui Yang [6] identified ARIMA(3,1,2) as the optimal model for their predictive analysis.

# ARTIFICIAL INTELLIGENCE MODELS

To forecast the prices of silver, gold, and platinum, our methodology integrates a combination of machine learning and statistical techniques. These includeGated Recurrent Units (GRU), Long Short-Term Memory networks (LSTM), Autoregressive Integrated Moving Average (ARIMA),

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## GRU

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To solve the vanishing gradient problem of a standard RNN, GRU uses, Update gate and Reset gate. Basically, these are two vectors which decide what information should be passed to the output. The special thing about them is that they can be trained to keep information from long ago, without washing it through time or removing information which is irrelevant to the prediction.

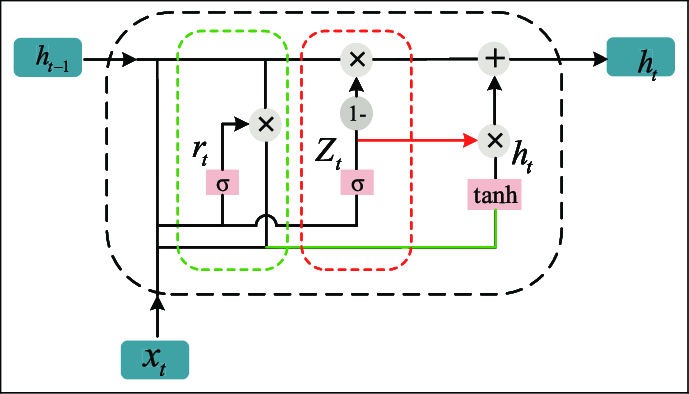


Figure . Gru model

The update gate helps the model to determine how much of the past information (from previous time steps) needs to be passed along to the future and avoid the vanishing gradient problem. The formula using for Update gate:

When is plugged into the network unit, it is multiplied by its own weight. The same goes for ℎ which holds the information for the previous t - 1 units and is multiplied by its own weight. Both results are added together, and a sigmoid activation function is applied to squash the result between 0 and 1.

Reset gate is used from the model to decide how much of the past information to forget. To calculate it, we use:

This formula is the same as the one for the update gate. We plug in ℎ — blue line and — purple line, multiply them with their corresponding weights, sum the results and apply the sigmoid function. The difference comes in the weights and the gate’s usage.

To determine what to remove from the previous time steps, we will calculate current memory content by using reset gate to store relevant information from the past.

To process input and ℎ, we multiply them by weights and respectively. The reset gate is used to determine what information to remove from previous time steps by calculating the Hadamard product with (ℎ). The results of steps 1 and 2 are summed up and passed through the tanh activation function.

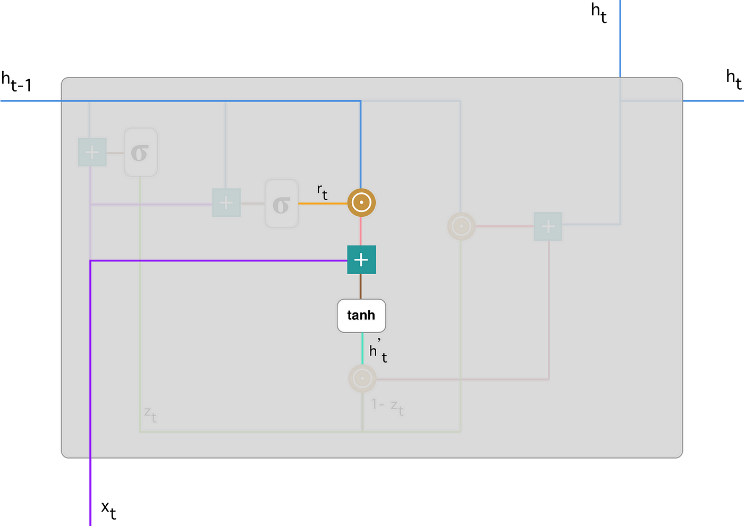


Figure . Current memory content

Finally, the network needs to calculate ℎ ℎ′ — vector which holds information for the current unit and passes it down to the network. In order to do that the update gate is needed. It determines what to collect from the current memory content — and what from the previous steps — ht-1. That is done as follows:

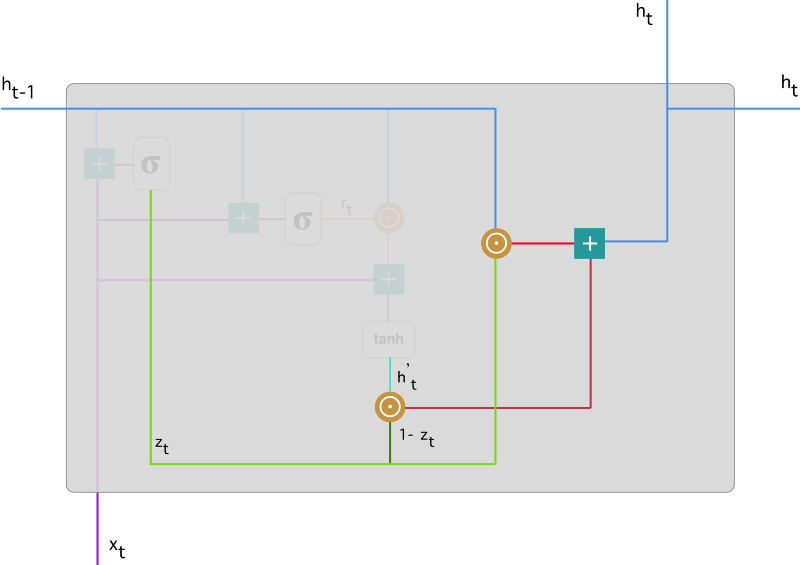


Figure . Final memory content

The model can learn to set the vector close to 1 and keep a majority of the previous information by apply element-wise multiplication to the update gate zt and ℎt-1. Since zt close to 1 at this time step, (1 − zt) will be close to 0 and ignore big portion of the current content, which is irrelevant for our prediction by apply element-wise multiplication to (1 – zt ) and . Final, we sum the results.[23]

## ARIMA

ARIMA is a statistical model that uses time series data to understand the dataset or predict future trends. Autoregressive models assume that the future will resemble the past and predict future prices based on past performance, but it can be inaccurate during certain market conditions. ARIMA analyzes the strength of one dependent variable compared to other changing variables and aims to predict future market moves by examining differences between values in the series.[12]

* The MA component predicts the value by accounting for the past errors or random "shocks" in previous observations. It aims to smooth out the time series by combining the random variations that were not explained.
* Auto regression (AR): The process of finding the relationship between the current data and p past data points (referred to as lags).

𝑦𝑡 : is the value of a dependent variable at time t

𝑎0 : is a constant term

𝑦𝑡−1, 𝑦𝑡−2, 𝑦𝑡−𝑝 : the dependent variables in the past

𝑎1,𝑎2*,* 𝑎𝑝 : are the coefficients of the lagged values of the dependent variables respectively

𝜀𝑡 : is the error term at time t

* Moving average (MA):

The MA component predicts the value by accounting for the past errors or random "shocks" in previous observations. It aims to smooth out the time series by combining the random variations that were not explained.

Where,

𝑦𝑡: is the value of a dependent variable at time t

𝛽0: is a constant term

𝜀𝑡−1, 𝜀𝑡−2, 𝜀𝑡−𝑞: the error terms in the past

𝛽1,𝛽2*,* 𝛽𝑞: are the coefficients of the lagged values of the error term respectively

𝜇𝑡: is the current error term or residual at time t

* ARIMA:

ARIMA(p,d ,q)= AR(p)+ I(d)+ MA(q)[13]

Where,

p, d, q: are non-negative integers representing the order of autoregression, differencing, and moving average respectively.

AR(p): Autoregression of order p refers to the regression of the variable on its own lagged values up to p lags. The AR(p) component captures the linear dependence between the current value and its past values.

I(d): Integration of order d refers to differing the time series d times until it becomes stationary. The I(d) component removes the trend from the time series.

MA(q): Moving average of order q refers to the regression of the variable on the past errors up to q lags. The MA(q) component captures the linear dependence between the current value and its past errors.

## LSTM

LSTM (Long Short-Term Memory) is a deep learning, sequential neural network that overcomes the vanishing gradient problem faced by RNN. It allows information to persist and works similarly to an RNN cell.

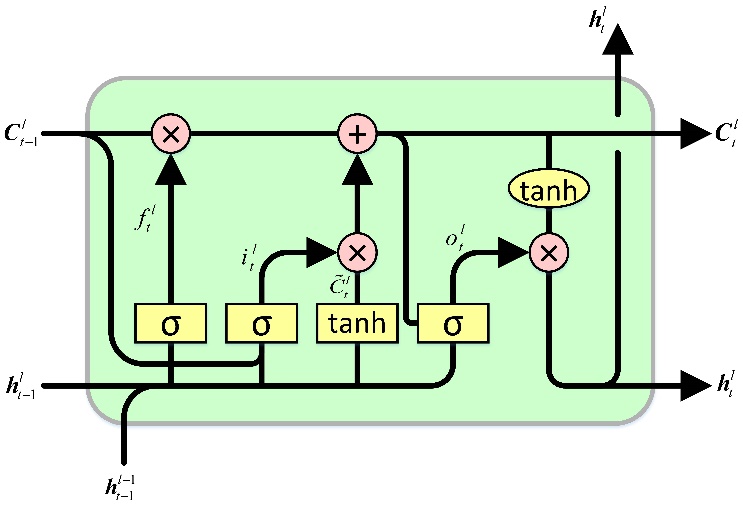


Figure . LSTM Architecture

An LSTM has a hidden state for short-term memory and a cell state for long-term memory. The cell state remembers important information over time while filtering out irrelevant data, allowing LSTMs to make accurate predictions.

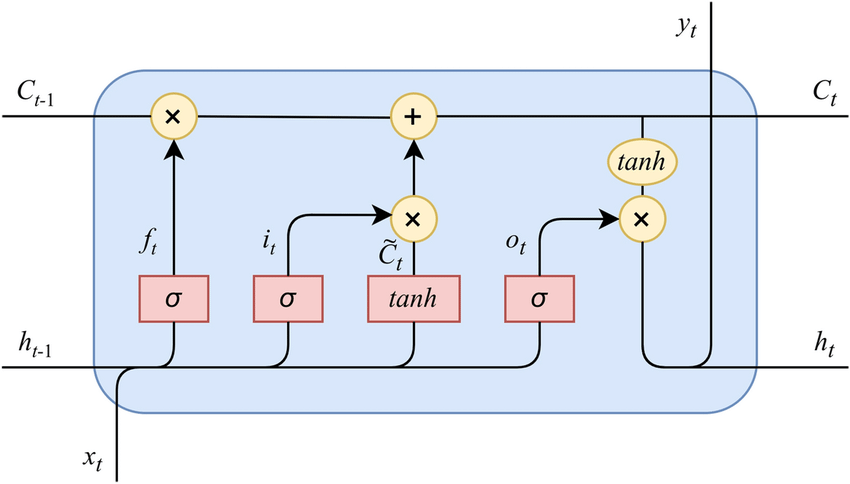


Figure . Long- and Short-Term Memory

LSTM has three gates that control the flow of information in and out of the memory cell: Forget, Input, and Output.

First, the Forget gate chooses whether the information coming from the previous timestamp is to be remembered or is irrelevant and can be forgotten.

1

𝜎 = 1 + 𝑒−𝑥

𝑓𝑡 = 𝜎(𝑊ℎℎ(𝑓) ℎ𝑡−1 + 𝑊ℎ𝑥(𝑓) 𝑥𝑡)

It determines how much information from the previous cell state 𝐶𝑡−1 should be retained for the current time step. It does this by taking a weighted sum of the previous hidden state ℎ𝑡−1 and current input 𝑥𝑡, with weights given by matrices 𝑊ℎℎ(𝑓)

and 𝑊ℎ𝑥(𝑓), respectively.

The result is passed through a sigmoid activation function σ, which squashes the values between 0 and 1. A value of 0 means that all information from the previous cell state will be forgotten, while a value of 1 means that all information will be retained.

Next, the Input gate tries to learn new information from the input to this cell and determines how much to take from the intermediate cell state.

𝑖𝑡 = 𝜎(𝑊ℎℎ(𝑖) ℎ𝑡−1 + 𝑊ℎ𝑥(𝑖) 𝑥𝑡)

In contract, the Input gate identifies how much information from the current input 𝑥𝑡 and previous hidden state ℎ𝑡−1 should be used to update the cell state 𝐶𝑡, with weights given by matrices 𝑊ℎℎ(𝑖) and 𝑊ℎ𝑥(𝑖), respectively.

Again, we have applied the sigmoid function over it. As a result, the value of 𝑖𝑡 will be between 0 and 1.

𝐶̃𝑡 = 𝑡𝑎𝑛ℎ(𝑊ℎℎ(𝑐) ℎ𝑡−1 + 𝑊ℎ𝑥(𝑐) 𝑥𝑡)

LSTM may not take everything from the intermediate cell state, the 𝐶̃𝑡 is there to distinguish between different weight matrices. Due to the 𝑡𝑎𝑛ℎ function, the value of new information will be between -1 and 1. If the value of 𝐶̃𝑡 is negative, the information is subtracted from the cell state, and if the value is positive, the information is added to the cell state at the current timestamp. However, the 𝐶̃𝑡 won’t be added directly to the cell state.

Here comes the updated equation :

𝐶̃𝑡 = (𝑓𝑡 \* 𝐶𝑡−1 + 𝑖𝑡 𝐶̃𝑡)

The Output gate passes the updated information from the current timestamp to the next timestamp. Together, they function as a layer of neurons with hidden layers and a current state.

𝑜𝑡 = 𝜎(𝑊ℎℎ(𝑜) ℎ𝑡−1 + 𝑊ℎ𝑥(𝑜) 𝑥𝑡)

Its value will also lie between 0 and 1 because of this sigmoid function. Now to calculate the current hidden state, we will use 𝑜𝑡 and tanh of the updated cell state. [21]

ℎ𝑡 = 𝑜𝑡 ∗ tanh(𝐶𝑡)

# RESULT

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