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PREDICTION OF GOLD PRICE MOVEMENT CONSIDERING THE NUMBER OF INFECTED WITH THE COVID 19[1]

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Abstract:
This paper aims to test several models and select the best one for predicting the price of gold on the world market for the next day, in five and ten days, taking into account the number of cases and deaths from the Covid-19 virus. These predictions can help decision-makers whether, at what point, and in what amount, it is best to invest in gold and gold-related financial instruments, relative to the projected price of gold from the model. The paper tests models called Decision tree, K-nearest neighbors, Linear regression model, and Support vector machines based on the information on gold prices and the number of cases and deaths from the Covid-19 virus. It will be seen in the paper that even models with only information on the price of gold give quite reliable predictions, but in unstable times like this, models that take into account the instability factor give more accurate predictions. The research aims to determine the optimal amount of information based on which the models will "learn" to give the most accurate possible result. This work's data processing and models are done in Python.

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INTRODUCTION

Throughout the history and development of economic systems, various goods and materials have played the role of money. At the time of barter, goods were exchanged for goods, whereas later it was possible to exchange goods of greater value for more goods of lesser value. Eventually, a system was established where one type of goods became the general equivalent of payment, accepted by all participants. For a large part of history, the function of money was performed by gold. That gold was in the form of coins of precisely determined quality, shape and weight, and in return, it was assigned a value. Naturally, bigger, heavier coins with higher purity had a higher value. Thus, one was able to get larger quantities of goods and services in return.

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Gold has always been considered a custodian of value and its basic function is to preserve purchasing power in times of great uncertainty. In the last few years, we have witnessed a period of great uncertainty in the health domain, which further led to uncertainty in the financial, market of goods and services, as well as in all other fields. A new virus called SARS-CoV-2 appeared in 2019 in China as an infectious disease that causes the severe acute respiratory syndrome. The World Health Organization (WHO) declared the Coronavirus outbreak of 2019/20 a pandemic and public health threat of international importance. Evidence of local disease transmission was found in several countries, i.e. in all six WHO regions.

Although the death rate from the virus was quite low at the very beginning, it increased over time, and the number of cases continued to grow. The pandemic was soon declared by WHO, which led to instability in the financial, but also in all other markets. This is best seen through the significant jump in the price of gold. Yousef and Shehadeh (2020) explain this situation quite well. Namely, they prove that there is a correlation between the number of patients and the jump in the value of the price of gold. That is why the research problem in this paper is the prediction of the price of gold in conditions of uncertainty, such as the outbreak of COVID-19.

There are many methods in the literature that make predictions of the price of gold based on historical data. These methods, although effective, lose precision when major market disruptions occur. Therefore, the topic of this paper is to prove that such models have less accuracy than models that include historical data on the cause of market disruptions, which in this case is the COVID-19 pandemic. This paper starts from the assumption that investors need to be able to follow the trend of gold prices, and this paper relatively accurately (over 90% accuracy) follows models that make predictions for tomorrow, the next five or ten days. In this way, investors can determine at what point and how much they can invest and thus get the most value. In addition, this kind of research helps those who operate in short-term markets, like the Forex market, where things change quickly. Such analyses can help them make the greatest possible profit in the shortest possible period of time. Predictions are of great importance for financial decision-makers. The data contained in the models this paper uses can easily be replaced by data on any other financial instrument in the event of a similar crisis that will almost certainly arise in the future. We believe this to be the greatest contribution of the paper.

BACKGROUND AND LITERATURE REVIEW

Concerning the importance of the gold price in the overall economic environment, predicting the price of gold is very significant. Different studies and models have been used for this purpose. In some eminent research, classical econometric methods were used for this prediction (Shafiee&Topal, 2010; Aye *et.al.*,2015). Different techniques for the gold price prediction, were used and although various models give very good results, the ARIMA (autoregressive integrated moving average) model is the most precise of all traditional statistical models (Yang 2019; Makala & Li, 2021). In addition, it is good to use a sliding dataset for the prediction (Brownlee, 2020). By comparing the models on the same data set for profit prediction it can be concluded that the choice of the dataset is very important and that parameters unrelated to gold can help make a better prediction (Riazuddin, 2020).

In some prominent research, the artificial neural network model was used for modeling the gold price and compared with the traditional statistical model of ARIMA. The three performance measures, the coefficient of determination (R2), root mean squared error (RMSE), and mean absolute error (MAE), are utilized to evaluate the performances of different models developed. The results show that the ANN

model outperforms the ARIMA model, in terms of different performance criteria during the training and validation phases (Mombeini & Chamzini, 2015; Hong&Majid, 2021).

Machine learning has often been applied to the prediction of financial variables, but usually with a focus on stock prediction rather than commodities (Megan, 2022; Chen *et al.* 2021). It has also been used for COVID 19 cases (Zivkovic *et al.* 2021) The application of machine learning in trading with financial instruments has shown very good results (Test&Broker, 2020; Sami&Junejo, 2017), including predictions of gold price direction (Perry, 2021; Aruna *et al.* 2021) especially by using a decision tree algorithm and support vector (Navin, 2015).

Covid-19 has damaged the global economy, as the series of lockdowns had negative impacts on the global economy (Altig *et al.* 2020; Borio 2020). Therefore, several studies intended to determine the relationship between COVID-19 infection rates and the price of gold. For this correlation different statistical analyses have been used such as the Vector Error Correction Model (Gautam *et al,* 2022) and GARCH model (Syahri & Robiyanto, 2020; Bentes *et al.* 2022; Abounoori & Zabol, 2020)

DATA

The time frame of the data set is dictated by the Covid-19 data set frame. Virus data and gold data are merged into one data set. For the models to be able to predict such a union of data, all N / A values have been dropped, and data regarding the value of gold start with the beginning of 2020, i.e. with the 1st of January. Also, the stock exchanges are closed from Friday from 4 pm to Monday at 8 am, and there is no weekend information.

A set of data containing information about gold was used from the Python library Yahoo! Finance. The following values were taken directly for prediction:

- **CLOSE** - THE VALUE INDICATES THE FINAL PRICE OF GOLD ON THE STOCK EXCHANGE FOR THE GIVEN DAY.
- **HIGH** - THE HIGHEST DAILY PRICE OF GOLD.
- **LOW** - THE LOWEST DAILY PRICE OF GOLD.
- **VOLUME** - DAILY TURNOVER, NUMBER OF TRANSACTIONS FOR THE GIVEN DAY.

Based on the close value, two columns were added, which represent the average price of gold in the previous three and nine days. The model is created based on the idea of Shah and Pachanekar (2020). This way of processing data is called moving average. It is good for making predictions for any given period and is also easily presented in a graph. When we take into account 3 days, this method is called simple moving average and is used as a significant indicator among brokers because it gives equal importance to all three prices and thus shows the price trend.

Data on the virus were taken from the website of the European Center for Disease Prevention and Control (opendata.ecdc.europa.eu, 2020). Since the data contains values for each country individually, they are grouped by date and aggregated into two categories, the number of cases per day and the number of deaths per day.

Figure 1. Gold price from the beginning of 2020

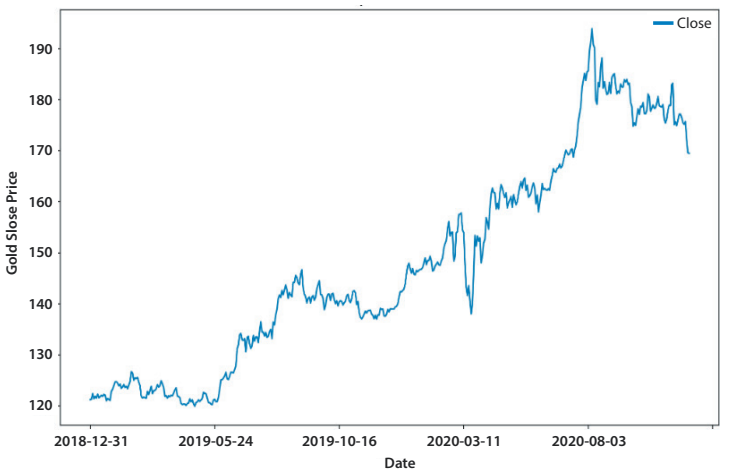


Figure 2. The number of people infected with the Covid-19 virus in 2020

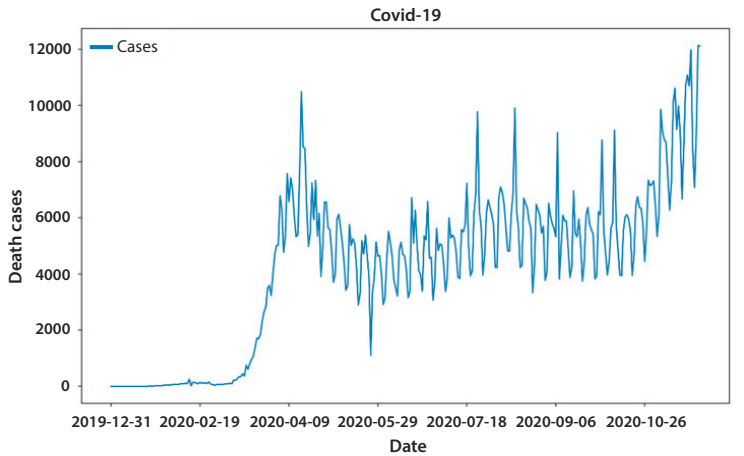
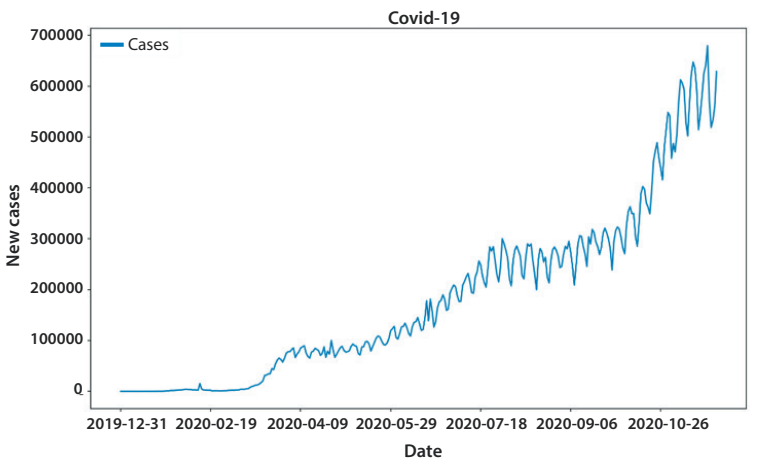


Figure 3. Number of deaths from Covid-19 in 2020

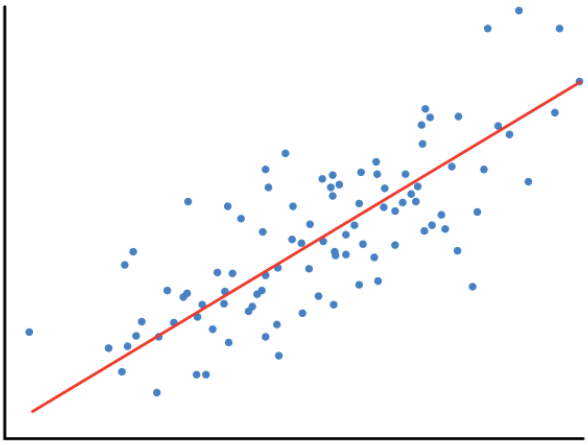


MODELS USED FOR THE RESEARCH

The paper uses four popular models of machine learning that apply the following algorithms: linear regression, the decision tree, K-nearest neighbour, A support vector machine.

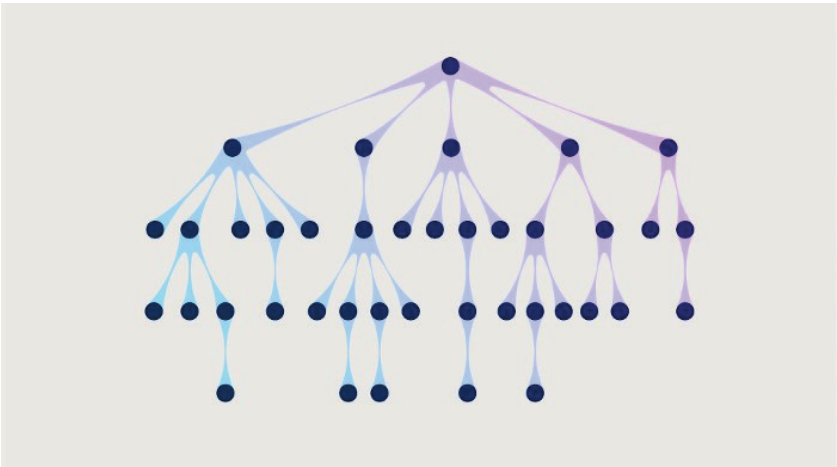
Linear regression tries to show the values of the dependent variable in the most accurate way possible about the independent variable with a linear function. This is a common way of predicting the value of financial instruments, especially if the values are inert. It is a process of finding a line between data points we already have, and we are using that line as an assumption that future data points will fall on it.

Figure 4. An example of linear regression (Thiebaut, 2019)



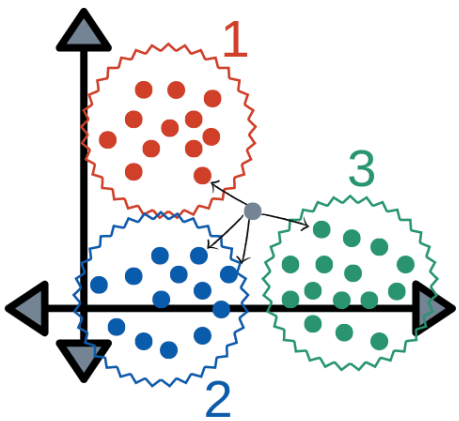
The decision tree is one of the best and most commonly used classification algorithms because, in addition to offering high prediction accuracy and clarity, it also easily maps nonlinear relationships. This algorithm easily solves regression and classification problems.

Figure 5. An example of the algorithm The decision tree (Jacobi, 2017)



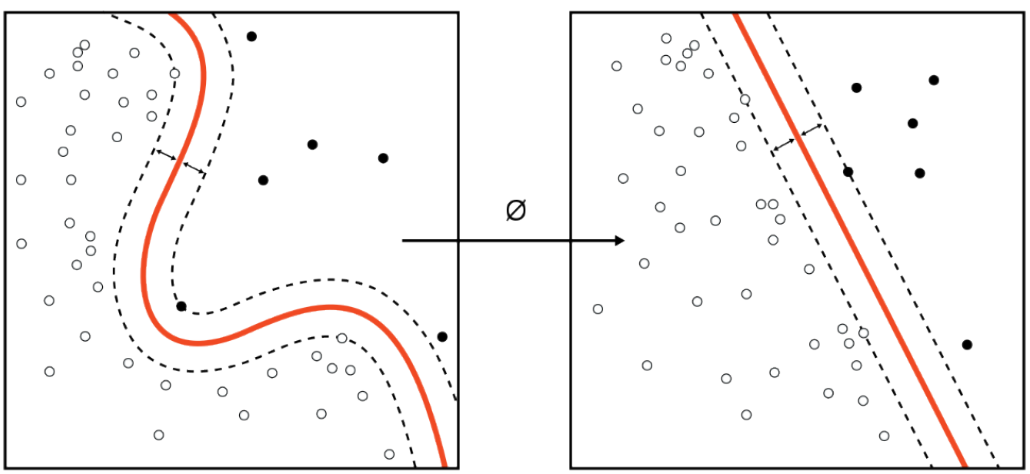
K-nearest neighbour (kNN) can be used for classification and regression problems. It is a model that classifies data points based on the points that are most similar to it. It uses test data to "learn how to guess" what to classify in an unclassified point. More specifically, one might wish to weigh the evidence of a neighbour close to an unclassified observation more heavily than the evidence of another neighbour that is at a greater distance from the unclassified observation (Dudani,1976).

Figure 6. An example of the kNN model (Schott, 2019)



A support vector machine (SVM) is a model reminiscent of a more advanced version of linear regression. This model presents data as points in space that it classifies into two categories between which there is a gap. The SVM efficiently constructs linear or nonlinear classification boundaries and is able to yield a sparse solution through the so-called support vectors, that is, through those observations that are either not perfectly classified or are on the classification boundary (Van Der Burg & Groenen, 2016). For the model not to be a linear regression model, the so-called kernel trick is used, which implies observing individual zones, and not the whole set.

Figure 7. An example of SVM model (Alisneaky, 2011)



RESULTS

This research intends to predict the price of gold for one, five, and ten days in advance by using the models of linear regression, decision tree, K-nearest neighbour, and support vector machine. We attempted to see whether one model gives relatively accurate predictions of these prices and which ones. The algorithms did not change in the testing itself, but the intention is to get the best result through changes in the variables. Unlike other papers and research, we were adjusting the amounts of data we will push into the model. This allowed us the workaround on models becoming inert and it helped with weekend stock market missing data and removed N/A values. In other words, it was important to find the model that makes the most accurate prediction for the next day, and later on to predict the gold price five and ten days in advance.

Due to the specific nature of machine learning models, testing and result representation are adequately adjusted, with multiple repeating independent runs taking place during testing, and results showing statistical results of multiple iterations. Additionally, various parameter settings were tested in search of optimal performance.

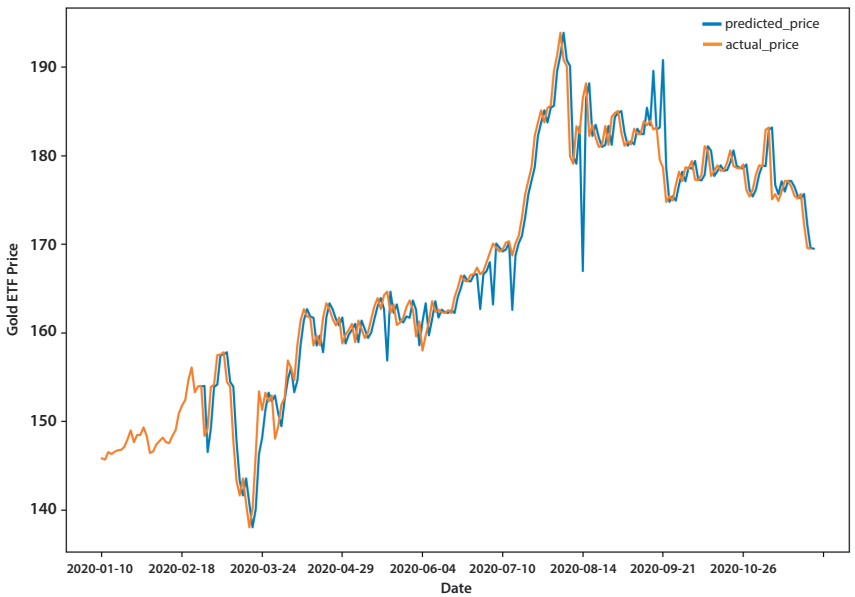
The first iteration we tested and took as a basis is the prediction of the gold price considering only the historical price of gold as one example, and the second one considering the historical price of gold together with the variables of the Covid-19 virus. The train set for the first example is thirty days, and each day contains information on the high, low and close price of gold, the volume of trade, the average price of gold for the previous three and nine days, and information on the number of patients and deaths from the Covid-19 virus for the previous ten days.

Table 1. Results of baseline gold price prediction models

	Linear regression		Decision tree		K-nearest neighbour		Supp. Vector machine	
	Gold	Gold and Covid-19	Gold	Gold and Covid-19	Gold	Gold and Covid-19	Gold	Gold and Covid-19
Explained_ variance_score	-35.4651	-1.8951	0.9389	0.8926	0.8614	0.8707	0.8472	0.8468
Max_error	895.4937	202.7006	19.5200	22.8000	16.8292	16.7699	14.5399	14.5689
Mean_absolute_ error	16.1152	8.4048	1.9061	2.4486	3.5294	3.4420	4.0318	4.0369
Mean_squared_ error	5268.3565	415.8096	8.8095	15.8995	23.3938	21.9165	27.2889	27.3527
Mean_squared_ log_error	0.06014	0.0102	0.0003	0.0005	0.0007	0.0007	0.0009	0.0009
Median_ absolute_error	3.6564	3.5801	1.2399	1.3899	2.4911	2.5083	3.2707	3.2654
r2_score	-35.6856	-1.8954	0.9386	0.8892	0.8370	0.8473	0.8099	0.8095

From the results of the first iteration, it was noticed that the most accurate prediction is given by the decision tree model, but completely contrary to our expectation, a more accurate solution is given by a model that takes into account only the historical price of gold.

Figure 8. Extreme values of decision tree model

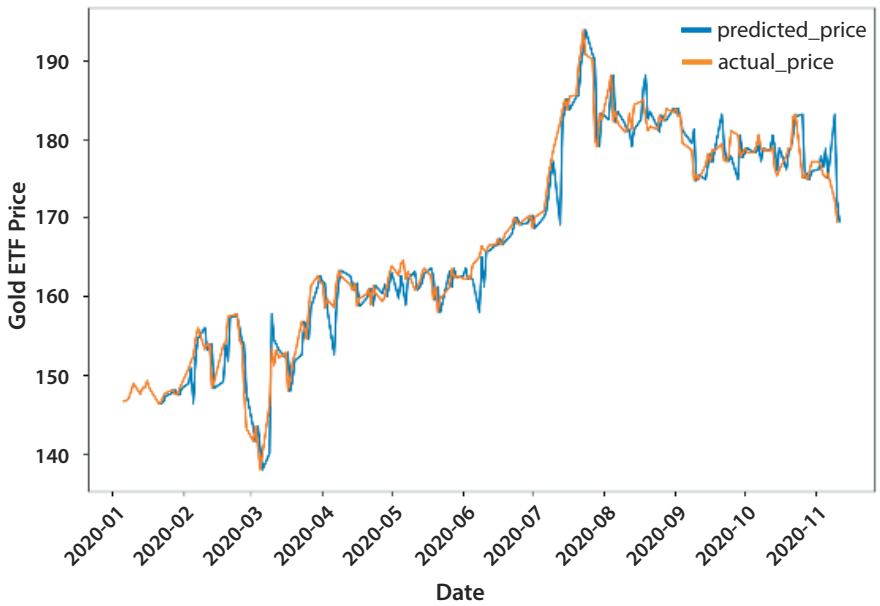


Also, it was noticed that the models have extreme values that do not appear in reality, and were probably caused by "trend velocity" that did not happen. Also, a large number of extreme values from models that include information about Covid are caused by weekend breaks in information. Based on that, it was decided to take the average of the number of patients and the number of deaths in the previous seven days instead of the ten-day data. This iteration in all models shows a more accurate prediction, and three of the four models show a more accurate prediction with information about the Covid-19 virus. Also, this gave us more accurate results, but not good enough.

Observing the results of the previous iteration, we concluded that the train set is potentially too large. It is based on the whole month-worth of information and potentially becomes inert, i.e. "overlearned". Therefore, for the next iteration, we left the data as it is, except that we set the train set to fifteen days.

From the results we noticed that all models give more accurate results. However, the best model turned out to be the decision tree model. It gives the best results both by looking only at the historical price of gold, but also the price of gold taking into account Covid-19 factors. Price prediction with Covid information is still more accurate in all models, only the support vector machine model gives a slightly less accurate result.

Figure 9. Model with Covid data without extreme values



Also, here we saw that with this way of looking at the data we managed to cancel almost all extreme deviations of the decision tree model. It is seen that the linear regression model gives the worst predictions and has the highest extreme values. The other two models do not have perfect prediction accuracy, but they follow the gold price trend very well, so their value is also reflected in that.

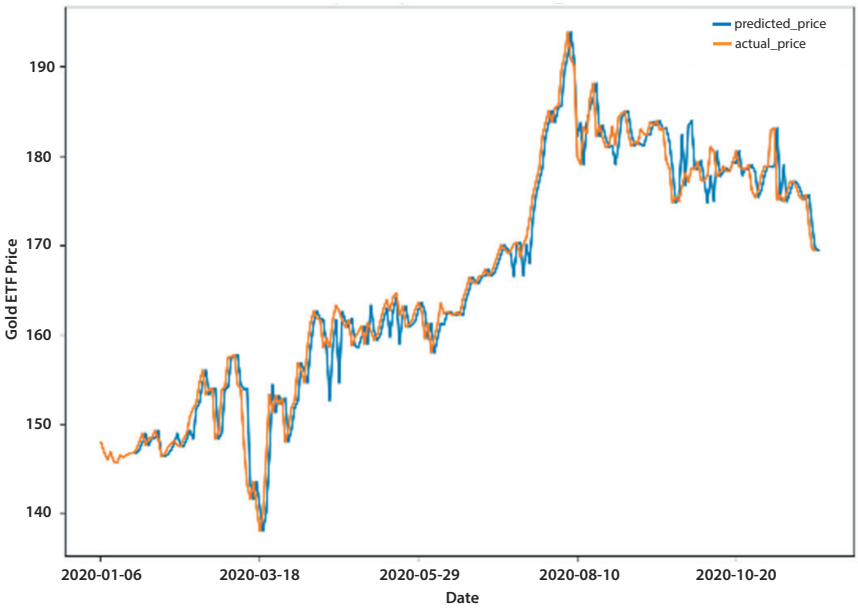
Believing that the problem with the previous iterations was a train set, we tried a seven-day train set, believing that this would avoid the problem related to the stock market operation and the problem related to the weekend data missing.

The presentation of the results tells us that the best model for predicting the price of gold for tomorrow is the decision tree model, which, in addition to the historical price of gold, also contains data on the number of patients and the number of deaths from the Covid-19 virus with a prediction accuracy of 96.25%. The second-best model is still the decision tree, which only contains information about historical gold prices.

Table 2. Results of gold price prediction models with the model with the greatest accuracy

	Linear regression		Decision tree		K-nearest neighbour		Supp. Vector machine	
	Gold	Gold and Covid-19	Gold	Gold and Covid-19	Gold	Gold and Covid-19	Gold	Gold and Covid-19
Explained_ variance_score	-0.6391	-0.6295	0.9616	0.9627	. 0.9386	0.9387	0.9307	0.9306
Max_error	143.1799	143.1799	10.7200	10.7200	13.4921	13.4722	11.3136	11.3128
Mean_absolute_error	6.6431	6.5635	1.8054	1.8054	2.4035	2.4021	2.5986	2.5994
Mean_squared_ error	274.9183	273.2479	6.4203	6.2792	10.7402.	10.7300	12.1284	12.1423
Mean_squared_log_ error	0.1156	0.1155	0.0002	0.0002	0.0003	0.0003	0.0004	0.0004
Median_ absolute_error	2.8622	2.8233	1.3300	1.2699	1.8060	1.8060	2.0386	2.0307
r2_score	**0.6412**	-0.6313	0.9616	0.9625	0.9358	0.9359	0.9275	0.9275

Figure 10. A graphic view of the most accurate model, decision tree with gold and Covid data



Additionally, we performed more iterations to see the prediction results for the prices five, that is, ten days in advance and the same model gives us the most accurate results with an accuracy of more than 95%. For the prediction of results made five days in advance for the first time, a model other than a decision tree gives more accurate results, in the case of prediction based on the historical price of gold. That model is the K-nearest neighbour with the accuracy of 93%. Surely, still the most accurate model is decision tree model with Covid-19 data, but KNN was a surprise.

Lastly, the price prediction for ten days in advance gave us unsurprising results. In this case these decision tree models give the most accurate results. It is interesting that the maximum error is the smallest in the support vector machine model, but all other parameters are the most favourable in the case of the decision tree model. This model predicts the price of gold in ten days with an accuracy of 95.40%.

CONCLUSION

Linear regression tries to show the values of the dependent variable as accurately as possible in relation to the independent variable with a linear function. Many research papers deal with the prediction of the price of gold with the help of linear regression, which can be explained by the relatively stable price of gold in the past, but due to the instability caused by the Covid 19 virus, this model does not give accurate predictions. In fact, of all the four models tested, this model can be called the least applicable for this type of prediction. We attribute this to the fact that the data do not follow any linear trend and are too "scattered" for this type of prediction to give meaningful results.

The k-nearest neighbour model shows the highest accuracy of the prediction in the case of predictions made five days in advance, and only on the basis of historical data on the price of gold. The maximum error of the model is always quite similar for both the model with historical gold prices and the model with the Covid virus.

The support vector machine model in almost every iteration shows more precise results when the prediction is made only on the basis of the historical price of gold. Similar to the k-nearest neighbour model, the accuracy of this model is almost always over 80%. The maximum error of this model is almost the same regardless of what data we take into account, and very often it is smaller than the model that has higher levels of accuracy.

In each iteration and in almost every case, except one, the accuracy of the decision tree model is the highest compared to other tested models. The highest accuracy, of 96.25%, is given in the model trained on a seven-day data set, with information on the seven-day average number of patients and deaths from the Covid-19 virus where the prediction was made for the next day. It is believed that this level of precision is very successful in conditions of great imbalance.

Based on all the above, it is believed that the hypothesis that information on the number of infected and infected with the Covid-19 virus helps to create models with greater accuracy in determining the price of gold than those with only historical values of gold prices has been proven.

Future research could focus on adjusting the parameters of algorithms for creating models and testing other models. It is also believed that such models can be applied not only to the situation with gold and the Covid-19 virus but also to determine the price of any financial instrument at any time in a crisis if appropriate quantifiers of the crisis situation are inserted. Given that health crises have become more frequent in the last few decades, it is believed that this work will have wide applications in the future.

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PREDVIĐANJE KRETANJA CIJENE ZLATA S OBZIROM NA BROJ ZARAŽENIH KOVIDOM 19

Rezime:

Ovaj rad ima za cilj da testira nekoliko modela i odabere najbolji za predviđanje cene zlata na svetskom tržištu za naredni dan, odnosno pet ili deset dana unapred, uzimajući u obzir broj obolelih i umrlih od virusa Covid-19. Ova predviđanja mogu da pomognu donosiocima odluka da li je, kada i u kom iznosu, najbolje investirati u zlato i finansijske instrumente vezane za zlato, u odnosu na projektovanu cenu zlata iz datog modela. U radu se testiraju sledeći modeli: Stablo odlučivanja, K-najbliži sused, model linearne regresije i mašine za vektore podrške na osnovu informacija o cenama zlata i broju obolelih odnosno umrlih od virusa Covid-19. Rad će pokazati da čak i modeli koji sadrže samo podatke o ceni zlata daju prilično pouzdana predviđanja, ali da u ovakvim nestabilnim vremenima modeli koji uzimaju u obzir faktor nestabilnosti daju tačnija predviđanja. Istraživanje ima za cilj da odredi optimalnu količinu informacija na osnovu kojih će modeli „naučiti" da daju što tačniji mogući rezultat. U ovom radu, za obradu podataka i modele korišćen je Pajton.

Ključne reči:

Cena zlata,
COVID-19,
Drvo odlučivanja,
K-najbliži susedi,
Model linearne regresije,
Mašina vektora podrške.