Forecasting of the Istanbul Stock Exchange (ISE) Return with a Golden Ratio Model in the Epidemic of COVID-19

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FORECASTING OF THE ISTANBUL STOCK EXCHANGE (ISE) RETURN WITH A GOLDEN RATIO MODEL IN THE EPIDEMIC OF COVID-19

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Abstract. A novel coronavirus called COVID-19 has spread rapidly all over the world in the recent days. This virus, which has become a global problem, has deeply affected the stock markets. This paper aims to present a new model based on the Golden Ratio by using the data for National 100 Index of Istanbul Stock Exchange (ISE). Having trained ISE data between 2017 and 2018, the forecasts for 2019 are made. For the first half of 2020, the data between 2018 and 2019 are trained and new forecasts are made. In the light of these forecasts, of all the compared models, our model performs better in terms of both accuracy rate and root mean square error(RMSE) values. It is already clearly seen that these results follow each other in the graphic that constitutes the forecasts of our model with the ISE data of 2020 and they are sometimes the same as well.

Keywords: ISE(Istanbul Stock Exchange), Fuzzy Time Series, Golden Ratio, Fibonacci Numbers, Covid-19.

AMS Subject Classification: 93C42, 11B39, 62P20.

1. Introduction and motivation

After the first case had been detected in Wuhan, China, the World Health Organization (WHO) declared the epidemic of the new coronavirus on 11th March 2020. In spite of originating in China, this virus that has rapidly spread around the world has wreaked havoc not only on Thailand , Korea and Japan but also on USA and Europe. It has been a threat to the health of all people since the early of 2020. According to the COVID-19 situation report released on 7th July 2020, there have been more than 11 million confirmed cases caused by this virus. Furthermore, these numbers have been increasing day by day ([42]). In order to cope with the current pandemic, at least three scientific communities have gathered in [6]. Accordingly, there have been a great deal of studies on the prediction of prevalence of COVID-19. Throughout the pandemic, various models based on fuzzy time series have been used in order to predict the COVID-19. For example, the neural network model with fuzzy response aggregation is presented in [28]. In order to forecast COVID-19 time series for countries around the world, a hybrid approach combining the fractal dimension and fuzzy logic is found in [8]. To forecast the cumulative numbers of COVID-19 infections in China, uncertain time series are used in [44]. The basic reproductive rate R_0 is estimated using an SEIR model to forecast the epidemic in China in [23]. Additionally, various models and approaches are proposed to analyze different situations which have caused the prevalence of COVID-19 outbreak across the globe. (see [4, 29, 38, 40]) Naturally, Turkey is among the most affected countries in this period. This adverse effect is most likely to continue in the days to come in [1]. For this reason, there are a lot of studies on the potential risks and possible scenarios of this effect on financial markets. (see [3, 5, 27, 34, 49])

The movements of stock price are undoubtedly affected by a wide variety of factors. Therefore, when the model on stock prices is developed, the most important point to be considered is to determine the factors affecting these movements. Admittedly, one of these factors is the previous

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period data that we have had. Likewise, Fibonacci number obtained as the sum of the two numbers prior to itself is used in many stock price models. (see [13, 16, 21])

As it is known from history, the economic and social impact of the Spanish pandemic-influenza, which broke out in 1918, increased with the second wave. Since the second wave which has begun in the recent days is thought to continue for a while, it is clear that there will be new fluctuations in the financial markets. So, in this paper, our main concern is to shed light financial investors on making better investment decisions under uncertainty. As for main contribution, our model based on fuzzy time series is realized to be useful to find the values the closest to the actual values compared to other models in literature. Also, this model could guide investors to analyze the peaks and troughs patterns, which are always crucial to where (on which point) they buy or sell. Thus, investors in the stock markets could be able to react price movements in time, whether in an uptrend or a downtrend. On the other hand, fuzzy logic exhibits very different mental tasks without requiring any measurement as well as more than a logical system. For this reason, while our model is constructed, fuzzy logic which is a method that has been around for 60 years and provides decision-making by predicting in uncertain situations, is used. (see more [48])

It is obvious that making consistent predictions for the stock prices is of great importance to investors. Given that we witness frequently the fluctuations in stock prices within the global markets, a need for developing various estimating models has naturally increased. In this paper, we propose a new Golden Ratio model through which predicts 2019 year data of ISE (Istanbul Stock Exchange) training ISE data between the years of 2017 and 2018. In order to do this, before introducing this model, in Section 2 and 3, the literature on fuzzy time series and the definition of Fibonacci numbers & Golden ratio is given respectively. Then, how they are used in stock price prediction is discussed. The method is presented in details step by step using sample ISE data in Section 4. Then, we compare the performance of the proposed method with the models in the literature and the ISE data of 2019 in Section 5. In order to predict the year of 2020, all ISE data are trained from the beginning of 2018 to the end of 2019 and these results are evaluated in Section 6.

2. Fuzzy time-series models

The studies on the fuzzy time series have become more and more popular in different areas such as weather forecasting [10,50] enrollments [11,12,36,37] stock price movements [18,19,41,45] etc. since every observation with uncertainty requires stable forecasts. It is of great importance to predict the fluctuations in stock prices especially resulting from economic crises and political developments. Additionally, there is no doubt that financial investors would like to protect their financial assets from unexpected fluctuations in order to minimize their risks. For this reason, when the literature is examined, it is easily realized that many stock price forecasting methods based on fuzzy time series have been developed and analyzed. Such methods, frankly speaking, remain to arouse interest and are widely used at present. In the literature, there are also studies on different methods and approaches using ISE (Istanbul Stock Exchange) data (for example [7, 35, 43])

The fuzzy set theory, which has a wide range of applications, was first introduced by Zadeh in 1965 [46]. The main objective of this theory is to form schemas for uncertainties arising from intrinsic ambiguity in order to solve different problems. In [47], Zadeh proposes linguistic values by expanding the fuzzy relations known as fuzzy mathematics. As known a special dynamic process with linguistic values based on Fuzzy theory, fuzzy time series are described in [36, 37] by Song and Chissom. Then, this modeling was used in many applications such as in stock price predictions, temperature estimations and enrollment forecasting etc. until 2004. In 2005, Yu developed FTS based on different forecasting accuracy methodology in [45]. Afterwards, in 2006, the stock index was used in FTS model proposed by Huarng in [20]. In 2008, the outpatient traffic at hospital was estimated through the revised FTS method in [14]. From 2008 to 2017, these studies continued. Type-2 fuzzy sets were proposed by Zadeh in 1975. This method is showed to be better in handling linguistic uncertainties in [9, 17, 26]. Google Scholar 'fuzzy set' query results show that approximately 2.190.000 documents are obtained [2]. FTSs have been used for more than 50 years not only within finance, engineering, applied mathematics and medical but also within control theory and artificial intelligence.

3. Fibonacci numbers and golden ratio

It is a indisputable fact that the Golden Ratio and Fibonacci numbers have many applications in both nature and different science areas. These numbers resulting from mathematical rabbit problem with $F_0 = 0$, and $F_1 = 1$ initial conditions are defined as follows

$$F_n = F_{n-1} + F_{n-2} \quad \text{for } n \geq 0. \tag{1}$$

The ratio of two consecutive term of this sequence $\{0, 1, 1, 2, 3, 5, ...\}$ converges the Golden Ratio $\tau = \frac{1+\sqrt{5}}{2}$ which draws interest in many fields in nearly all domains of science (see details [24, 25, 30–33, 39]). Among the examples that can be given in the architectural field are the pyramid located in Gizza and United Nations Building. Moreover, $x^2 = x + 1$ the positive root of the algebraic equation is the Golden Ratio which is an irrational infinite number. As well as the mathematical features of this number, this ratio also represents aesthetic beauty in nature. For example, in [22], we encounter this number in a wide variety of fields such as the ratio of some parts of the human body to each other, the number of flower petals, the growing of the seed pods on a pinecone and tree branches etc.

On the other hand, financial models have been recently of great importance in predicting the increases and decreases in stock prices. Of all these models, one of the most well-known for nearly 60 years has been the Elliot Wave Principle [15] being a technical analysis method. This theory is based on two types of wave, namely 'impulse and corrective waves'. While the impulse waves move in the same direction as the main trend, the corrective waves move in the opposite direction. As shown in the Fig.1, the waves $1-3$ and 5 move in the trend direction whereas the waves 2 and 4 display correction behavior. What is pointed out here is that the corrective waves do not fall below both the previous peaks and trough.

In addition to forming the Fibonacci Numbers of the combination of waves, the Golden Ratio is equivalent to the ratio between some wavelengths. This ratio, which is accepted to be a law of nature, predicts that the current trend of the market will be completed and the market will enter a new trend.

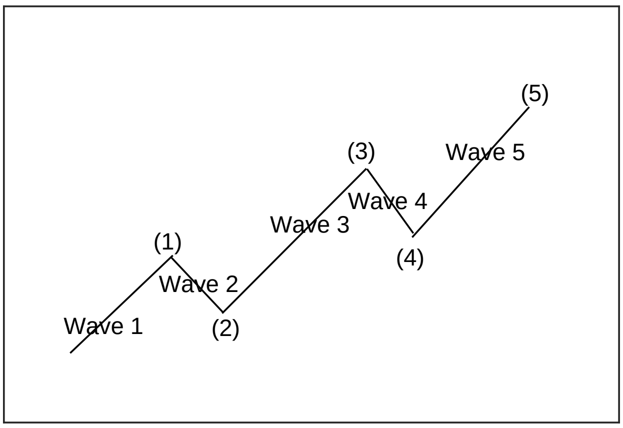

Figure 1. Elliot Wave Principle

4. Proposed model

The purpose of this section is to explain the working logic of model by using 2017-2019 years data for National 100 Index of Istanbul Stock Exchange (Istanbul Stock Exchange). It should be noted that the data between the years of 2017 and 2018 are used as a training set, while the data for 2019 is considered as a prediction set. In the light of the data obtained, the Golden Ratio has been used as a parameter to get more realistic predictions. In fact, choosing this parameter, many rational and irrational numbers are tried. It is seen that the closest results to the real ISE values are obtained by using the Golden Ratio. In addition, this model differs from classic fuzzy time series(FTS) models. That is to say, when the first data of 2019 is estimated, the ISE final data for 2018 is processed. This model is built on this logic.

Step 1: Define the universe of discourse and intervals

In this step, the maximum and minimum values of two years of Istanbul Stock Exchange data are calculated. The universe of discourses, $U = [D_1, D_2]$, is defined in order to contain all data of the time series where D_1 and D_2 are positive integers. As seen in the data set, D_1 is rounded to 76 that has a smaller value in training set and similarly to 121 that has a greater value than D_2. Subsequently, the determined sub-ranges corresponding to set, U, are created as shown in the table 1. According to the universe of discourse for observations U, the lengths of the intervals are determined as 5, 6 and 7 units respectively. It should be noted that n, which is the number partitioning intervals, is 8 as follows in the Table 1:

Table 1. A fragmentation of discourse.

Partition Intervals	Ranges
U_1	[76,81]
U_2	[81,87]
U_3	[87,92]
U_4	[92,98]
U_5	[98,103]
U_6	[103,109]
U_7	[109,114]
U_8	[114,121]

Step 2: Set up Linguistic Values

In this step, the fuzzy sets, $L_1, L_2, ..., L_k,$ are defined for each observation. The relations in this section are based on the following Definition 1.

Definition 1. Each linguistic observation, L_i,can be defined by the intervals $u_1, u_2, u_3, .., u_b$ as follows:

$$L_i = f_{L_1}(u_1)/u_1 + f_{L_2}(u_2)/u_2 + ... + f_{L_b}(u_b)/u_b \tag{2}$$

where $f_{L_i}(u_i) \in [0, 1]$.

In order to create the related linguistic values, the fuzzy sets, L_1, L_2, ..., L_8, can be established as follows:

$$\begin{aligned}
L_1 &= 1/u_1 + 0.5/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0/u_7 + 0/u_8 \\
L_2 &= 0.5/u_1 + 1/u_2 + 0.5/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0/u_7 + 0/u_8 \\
L_3 &= 0/u_1 + 0.5/u_2 + 1/u_3 + 0.5/u_4 + 0/u_5 + 0/u_6 + 0/u_7 + 0/u_8 \\
L_4 &= 0/u_1 + 0/u_2 + 0.5/u_3 + 1/u_4 + 0.5/u_5 + 0/u_6 + 0/u_7 + 0/u_8 \\
L_5 &= 0/u_1 + 0/u_2 + 0/u_3 + 0.5/u_4 + 1/u_5 + 0.5/u_6 + 0/u_7 + 0/u_8 \\
L_6 &= 0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0.5/u_5 + 1/u_6 + 0.5/u_7 + 0/u_8 \\
L_7 &= 0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0.5/u_6 + 1/u_7 + 0.5/u_8 \\
L_8 &= 0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0.5/u_7 + 1/u_8.
\end{aligned}$$

For the ISE data between the years of 2017 and 2018, the eight linguistic values are defined $L_1 =$

(*very low price*), L_2 = (*low price*), L_3 = (*little low price*), L_4 = (*normal price*), L_5 = (*slightly higher than normal price*), L_6 = (*higher than normal price*), L_7 = (*high price*) and L_8 = (*very high price*) based on the Definition 1.

Table 2. Assign linguistic values for each stock price value

Time	Stock Price	Linguistic values
$t = 27.10.2017$	107.884	L_6
$t = 30.10.2017$	108.467	L_6
$t = 31.10.2017$	110.143	L_7
$t = 1.11.2017$	113.024	L_7
$t = 2.11.2017$	112.995	L_7
$t = 3.11.2017$	111.293	L_7
$t = 6.11.2017$	114.166	L_8
$t = 7.11.2017$	112.272	L_7

Step 3: Create FLRs

In this step, we establish $FLRs$ for linguistic values.

Definition 2. If the stock price values in the days t and $t+1$ are L_i and L_j respectively, then this FLR is established by $L_i \to L_j$.

Stock price values are given as a sample and the linguistic values corresponding to these values are shown in the Table 2. The FLR table corresponding to the sample data set is given in the Table 3 with the help of the Definition 2.

Table 3. FLR.

...
$L_6 \to L_6,\ L_6 \to L_7,\ L_7 \to L_7$
$L_7 \to L_7,\ L_7 \to L_7,\ L_7 \to L_8$
$L_8 \to L_8$...

Step 4: Construct with Fluctuation-Type Matrix

In order to train the fuzzy relations in these $FLRs$, a fluctuation-type matrix is produced. To do this, the FLR weight is found by its order of occurrence. The fluctuation-type matrix containing the FLR values for all data in Table 4 is shown below.

Table 4. The fluctuation-type matrix of all ISE data between the years of 2017 and 2018.

	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	$\sum w_k$
L_1	8	1							9
L_2		13	1						14
L_3			74	8					82
L_4			8	109	7				124
L_5				7	47	7			61
L_6					8	73	10		91
L_7						12	30	8	50
L_8							8	45	53

Step 5 Sum up weight for the FLR

In this step, the fluctuation weight assignment is performed for each FLR group. Before this computation, the following definition should be included.

Definition 3. $W_{L_i \to L_j}$ is called the assigned weight for the FLR and it can be defined as follows

$$W_{L_i \to L_j} = \sum_{k=0}^{f(L_i \to L_j)} k \tag{3}$$

where occurence frequency and the order of $L_i \to L_j$ are $f(L_i \to L_j)$ and k, respectively.

With reference to this definition, the Table 4 shows the fluctuation-weighted matrix of all FLR.

Step 6 Find the standardized weights

In this step, the standardized weights are obtained from the following Definition 4.

Definition 4. The standardized weight matrix, $W_n(t)$, is defined

$$W_n(t) = [W_1', W_2', ..., W_i'] = [\frac{W_1}{\sum_{k=1}^{i} W_k}, \frac{W_2}{\sum_{k=1}^{i} W_k}, ..., \frac{W_i}{\sum_{k=1}^{i} W_k}]. \tag{4}$$

In doing so, the standardized weight matrix is constituted based on the Table 4. For example, with the help of the Table 4, the standardized weight matrix for L_1 is found as follows

$$[W_1', W_2', ..., W_8'] = [8/9, 1/9, 0, 0, 0, 0, 0, 0]. \tag{5}$$

Step 7: Compute the spread center of linguistic values and defuzzify

The spread center of linguistic value is computed using the following Definition 5.

Definition 5. v_i, which is the spread center of the observations, is defined for each L_i value as follows:

$$v_i = \frac{\sum_{k=1}^{n} u_{ik}\ x_k}{\sum_{k=1}^{n} u_{ik}}, \tag{6}$$

where u_{ik} is the membership function of linguistic value L_i; x_k is the observation value.

The data obtained from step 6 are used in order to perform defuzzification process. Each linguistic data is collected and their spreading centers are calculated. According to the Table 2, $v_6 = \frac{107.884+108.467}{2} = 108.175$, which is the spread center value of L_6, is found. With data created, the forecasting data are produced. The Table 5 shows all the standardized weight matrix including both previous computations and the forecasting data.

Step 8: Forecasting

In this step, the model related to the proposed method is introduced using the forecasting values stated in the Table 5.

To get the results closer to actual values, the parameters, $\pm\tau = \pm\frac{1+\sqrt{5}}{2} = \pm 0.61803$, are used. When creating the first forecasting data, the latest value of training set is used. In doing so, for the second forecasting data, the closing value of ISE on 28th Dec. 2018 is taken into consideration. The different parameters are tried for the current training set. And so, the results closer to actual values are obtained by the proposed method below

$$\begin{aligned} GoldenForecast(t) &= P(t_{last} - t + 1) + \tau(Forecast(t) - P(t-1)) \\ &\quad -\tau(Forecast(t-1) - P(t-2)). \end{aligned} \tag{7}$$

5. Evaluation of the performance of the Golden Ratio modelfor 2019

i) Accuracy rate values of models

In this section, the accuracy rate is calculated comparing the increases and decreases in daily values of all models with the values of previous days. When the increases or decreases in the values of ISE and other models are compared to the previous day, this case is accepted positive in the event of the similar case. And so, all these positive cases are counted. For example, according to Fibonacci model, this value is positive in 25 of the 42-days total in January and February 2019 and this value is found 124 for all months. Since the number of days considered

Table 5. The defuzzification process.

Time	*Stock Price*	Linguistic value	Defuzzy	Forecast
$t = 1$	107.884	L_6	$[0, 0; 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0, 0, 0, 0, 8/91, 73/91, 10/91]$	
$t = 2$	108.467	L_6	$[0, 0; 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0; 0, 0, 0, 8/91, 73/91, 10/91]$	111.856
$t = 3$	110.143	L_7	$[0, 0, 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0, 0, 0, 0, 12/50, 30/50, 8/50]$	111.386
$t = 4$	110.143	L_7	$[0, 0; 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0; 0, 0, 0, 12/50, 30/50, 8/50]$	111.386
$t = 5$	110.143	L_7	$[0, 0; 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0; 0, 0, 0, 12/50, 30/50, 8/50]$	111.386
$t = 6$	110.143	L_7	$[0, 0; 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0; 0, 0, 0, 12/50, 30/50, 8/50]$	111.386
$t = 7$	110.143	L_8	$[0, 0; 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0; 0, 0, 0, 8/53, 45/53]$	111.944
$t = 8$	110.143	L_7	$[0, 0; 0, 0, 0, 108.175, 111.945, 114.166]$ $\times [0, 0; 0, 0, 0, 12/50, 30/50, 8/50]$	111.386

is 259, this rate is 124/259 for Fibonacci model. It can be easily realized that the Golden Ratio has the highest accuracy value among all models.

Table 6. The comparison of the accuracy rates of all models.

	Jan-Feb	Marc-Apr	May-Jun	Jul-Aug	Sept-Oct	Nov-Dec	Accuracy rate
Fibonacci Model	25	21	22	15	20	21	0.478
Chen Model	13	10	11	15	8	20	0.297
Golden Ratio Model	24	24	23	24	21	22	0.532

ii) RMSE values of models

For evaluating the forecasting performance of models, root mean square error (RMSE) is defined as indicated in equation 8

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} |actual(t) - forecast(t)|^2}{n}}. \tag{8}$$

In this section, RMSE values are found for the year of 2019 predictions of all models. A total of 501 training ISE data sets (available between 02/01/2017 – 31/12/2018) are used. When the

Table 7 is examined, the RMSE values for the existing Fibonacci and Chen models turn out to be greater compared to the Golden Ratio model. According to this performance test, of all the other existing models, the Golden Ratio model that we have proposed is realized to be the best model.

Table 7. The comparison of the accuracy rates of all models.

Models	Total Testing Days	Time Period	RMSE
Fibonacci Model	259	02/01/2019-31/12/2019	20.1123
Chen Model	259	02/01/2019-31/12/2019	24.9545
Golden Ratio Model	259	02/01/2019-31/12/2019	17.725

6. Forecasting of ISE data in the epidemic of Covid-19 period of 2020

In this section, after training ISE National 100 Index data from Jan. 2th in 2018 to Dec. 31th in 2019, the ISE values based on the Golden Ratio model are predicted for the first half of 2020. When calculating these predictions, the daily ISE data are taken into account. In the table 6, there is a sample data set containing the results of all models in 2020. As can be seen from this table, the data based on Golden ratio is created at first. Then, the difference between the ISE data dated Jan. 2th in 2020 and the data that we have forecasted for that day is computed. This difference value is approximately 5.891 and the closest Fibonacci number to this difference value is 5. This difference is named as 'Fibonacci Key'. Subsequently, the forecasted value is 108.736 on Jan. 3th in 2020 and this fibonacci key is added. Afterward, the estimated value is created. In doing so, the difference is computed between the ISE value of the previous day and the forecasted value for that day. Then, the fibonacci key is found and similar addition is done. All forecasting values are created in this way. Also, the Table 8 includes predictions for Fibonacci and Chen models trained for 2 years. When the Fig.2 is examined in detail, it is possible to see how closely ISE data and Golden Ratio model data follow daily each other in January, 2020.

Table 8. A sample of forecasts of all models in 2020.

Dates	*ISE 100 index*	*Fibonacci Key*	*Golden Ratio Model*	Daily Forecasting Values	*Fibonaccci Model*	*Chen Model*
02-01-2020	115.932	–	110.041	–	118.939	116
03-01-2020	113.684	5	108.736	113.736	117.763	116
06-01-2020	111.412	5	108.489	113.489	116.936	116
07-01-2020	112.599	3	108.732	111.732	116.937	116
08-01-2020	112.876	3	109.014	112.014	116.733	116
09-01-2020	117.99	5	108.577	113.577	116.828	116
10-01-2020	118.663	8	107.871	115.871	116.594	116
13-01-2020	120.249	13	106.574	119.574	116.880	116
14-01-2020	121.423	13	107.079	120.079	118.261	116
15-01-2020	120.938	13	106.992	119.992	118.281	116
16-01-2020	121	13	107.542	120.542	117.660	116
17-01-2020	121.474	13	106.085	119.085	117.241	116
20-01-2020	122.619	13	105.974	118.974	117.214	116
21-01-2020	123.556	13	104.891	125.891	115.370	116

Our main target in this paper is to see the performance of the Golden Ratio model at the beginning of 2020, especially in the period of the pandemic which has had a adverse affect on all the global markets. For this reason, this Table 8 is created for the first six months of 2020. So, the accuracy rates of all models and RMSE (Root Mean Square Error) values are examined. The following Fig.2 shows the values daily obtained for all models.

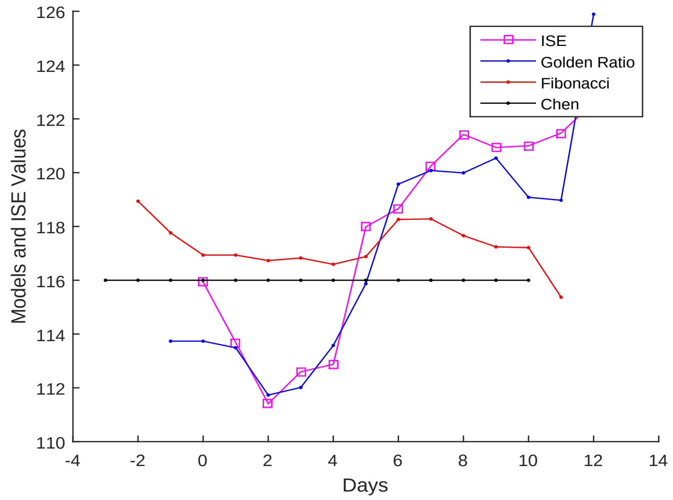

Figure 2. Plot of forecasts of all models in January, 2020

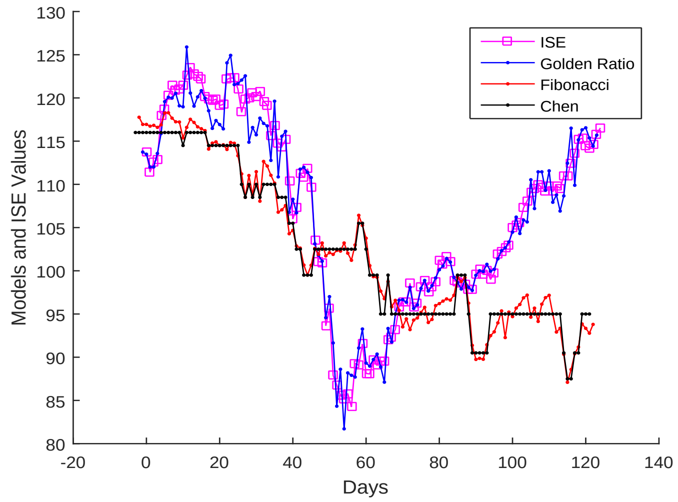

Figure 3. Comparison of forecasts for the first six months the year of 2020

Examining the Fig.3 in details, the values that we have forecasted for 2020 coincide with the ISE National 100 index values. For example, from 11th March 2020 (51th work day of ISE) when the first covid case in Turkey was detected to 13th March 2020 (53th work day of ISE) when the relatives of this patient were diagnosed, the ISE data decreased approximately 5 points in this range. Also, the ISE values have started to rise since the pandemic was normalized on 1th June 2020 (106th work day of ISE). These ISE values and the data of our method are not only very close to each other but also coincide with each other even during this period. Even if there are some exceptional deviations, it can be clearly seen that the results of model that we have forecasted are very close to the ISE data throughout this period. It can be said that the graph that creates the ISE data is a more smoothed version of our method. Namely, if we draw the ups and downs in our model's graphic, we get a graphic close to the ISE graphic.

The RMSE and accuracy rate values of all models are given in the Table 9. When these values are analyzed in detail, we see the RMSE values of our model decrease in March when there was a dramatic decrease in the ISE values. In addition, the maximum RMSE value of our model is close to 4 in the first six months of 2020, while this value is at least around 4 in other models. On the other hand, when the accuracy rate is evaluated, we realize that the Golden Ratio model has the RMSE value which gives the closest result to 1.

Table 9. Accuracy Rate and RMSE values of all models in 2020.

Models	Months	RMSE Values	Total	The number of daily increase/decrease	Accuracy Rate
Fibonacci Model	January	4.4501	57.7529	10	0.464
	February	7.1887		6	
	March	12.2733		11	
	April	5.3710		9	
	May	7.9699		11	
	June	20.4999		11	
Golden Ratio Model	January	2.1585	14.5727	13	0.519
	February	3.3537		11	
	March	3.8417		12	
	April	1.6290		11	
	May	0.9717		11	
	June	2.6181		8	
Chen Model	January	4.9599	57.869	2	0.136
	February	7.1226		7	
	March	12.1406		4	
	April	5.6428		1	
	May	7.5466		2	
	June	20.4565		1	

7. Conclusion and future work

Due to the COVID-19 epidemic that emerged in China in the early of 2020 and spread to the whole world in a short time and its negative effects on the financial markets, the measuring of the performance of our model has recently become more and more important. Considering that a number of stock markets across the globe have collapsed, this model can be said to be a good model that yields the consistent results even in this term. For this reason, before analyzing stock market mobility in 2020, 2019 performance values of the proposed method are measured. To this end, Chen model, which is one of the oldest models in the literature and Fibonacci model, which gives the closest results to the method that we have proposed, are examined. The performance results reveal that the Golden Ratio model forecasts successfully the ISE(Istanbul Stock Exchange) values for 2019 with an accuracy rate of 53.2% in comparison with other models . Similarly, the performance of the model is evaluated by calculating the RMSE value. The RMSE value of the Golden Ratio model is found 17.72. So, it is seen to be best model used to predict the ISE(Istanbul Stock Exchange) values for 2019.

In the first half of 2020, because of the pandemic, the financial markets in Turkey began to fluctuate. When the predictions of the Golden Ratio model for 2020 are examined, both the RMSE and the accuracy rate ratios are realized to yield significantly better results. In order to test the performance of the model in 2020, the MSE(Mean Square Error) method is also used. According to this method, our method (6.8438) has the best performance in the first six months of 2020 compared to the Fibonacci (112.4326) and Chen(111.7675) models. So, this model can be used as a good tool for investors. In practice, at the end of the day, the investors find the Fibonacci number closest to the difference between that day's ISE value and the model's predicted value for the next day. Investors add with this Fibonacci key with the predicted value of that day. Thus, according to this value obtained for the next day, the investors will be able to make decisions to buy or sell in this way.

Given the future studies on this topic, it is thought that it will produce the consistent results for the remaining half of 2020 of our model. For this reason, the effect of this model on stock prices will be followed in the days to come. In addition, this study that yields good results for Turkey could be extended to predict the price movements in other countries' stock markets.

With regard to economic indicators, our model could be applied to predict oil prices trend which of vital importance to world economy, notably during this economic recession that COVID-19 outbreak has triggered. Besides, the Golden Ratio model could be used to envisage certain economic indicators and price movements such as exchange rates, gold prices, raw material prices, food prices etc. which have significantly fluctuated since the beginning of pandemic. Considering that the cryptocurrencies or virtual currencies might become widespread and replace cash money in the markets in future, the price movements of virtual currencies could be predicted with the improved models.

As for the data of COVID-19, the model is practical to predict the number of new cases diagnosed, asymptomatic cases and patients recovered etc. Given that healthcare systems need better and more timely data, the forecasted values based on fuzzy time will come in handy for policymakers around the world to take preventive precautions in time.

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