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FORECASTING OF GOLD PRICE USING INTUITIONISTIC FUZZY TIME SERIES MODEL

by

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ABSTRACT

Gold price forecasting using intuitionistic fuzzy time series forecasting model and compare the performance of Intuitionistic fuzzy time series model to the other models.

KEYWORDS

Gold price, Forecasting model, Time series, ARIMA, IFTS model

1. INTROUCTION

Predictability of gold prices is important in many aspects of daily life, including the political, financial, and economic environments. To estimate the gold price using price history that depends on various economic factors. Price prediction plays an important role in economic decision making and used in numerous applications. Many studies have been conducted to predict trends in the price of gold. Several methods have been developed and implemented for the prediction of gold price. The forecasting methods can be classified into three main methods:

- (i) Traditional mathematical model
- (ii) Artificial Intelligence (AI)
- (iii) Hybrid models.

2. DATA AND METHODOLOGY

IFTS model (Intuitionistic Fuzzy Time Series Forecasting Model)

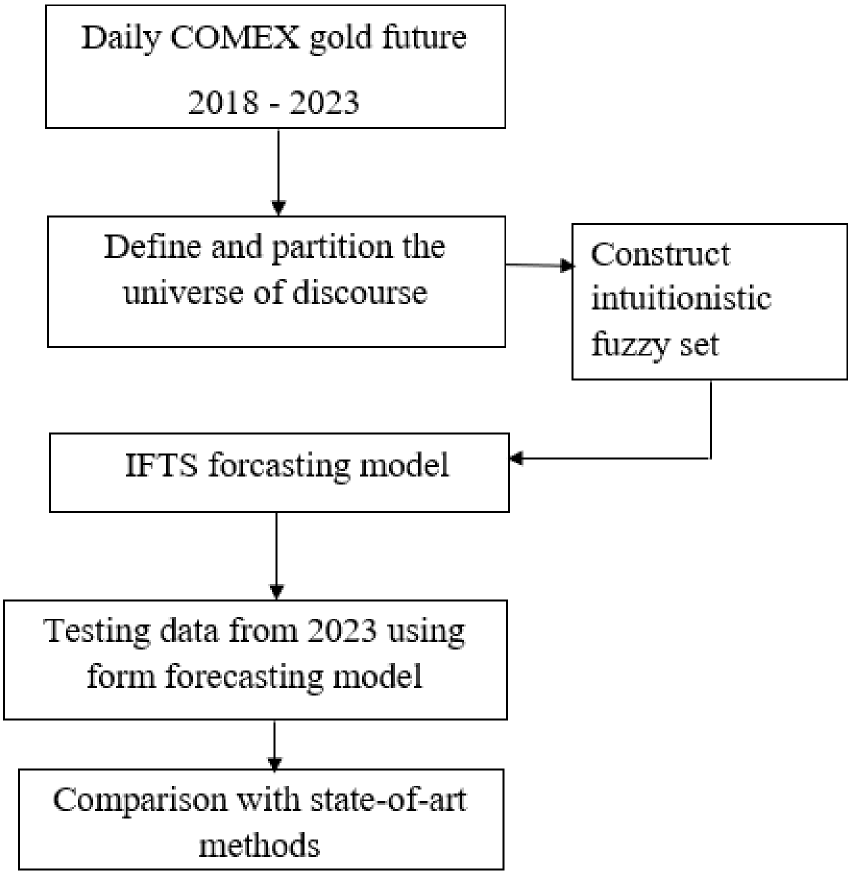

Figure 1

Collected gold price data during the years 2018 to 2023 from the Market Watch database's monthly prices for COMEX Gold futures. The primary international gold benchmark is the COMEX Gold price.

3. PROCEDURE

IFTS model (Intuitionistic Fuzzy Time Series Forecasting Model) The IFTS model can be summarized in four steps as the FTS model:

- Define and partition the universe of discourse.
- Construct intuitionistic fuzzy set and intuitionistically fuzzify the historical data.
- Establish forecast rules and get the forecasted value.
- Defuzzify and output the forecast result.

The rest of this section will detail the proposed IFTS model following this procedure

3. 1 Unequal Universe Partition

Unequal Universe Partition Based on Fuzzy Clustering.
First of all, the universe of discourse

$$U = [x_{min} - \varepsilon_1, x_{max} + \varepsilon_2] \qquad (1)$$

should be defined, where $x$min and $x$max are the minimum and maximum historical data, respectively. ε_1 and ε_2 are two proper positive numbers. Usually, for simplicity, ε_1 and ε_2 are chosen to round down $x$min and round up $x$max to two proper integers.

$$d_i = \begin{cases} x_{min} - \varepsilon_1, & i = 0 \\ \dfrac{x_i^{n_i} + x_{i+1}^{1}}{2}, & i = 1,2,\ldots.r-1 \\ x_{max} + \varepsilon_2, & i = r. \end{cases}$$

Secondly, partition the universe U into several intervals.
Therefore, we partition the universe U into r unequal intervals:

$u_1 = [d_0, d_1], u_2 = [d_1, d_2], \ldots,$ and $u_r = [d_{r-1}, d_r]$.

3. 2 Construction of Intuitionistic Fuzzy Sets.

$$A_i = \{\langle x, \mu_{A_i}(x), x, \gamma_{A_i}(x)\rangle | x \epsilon X\}, \quad i = 1,2,\ldots,r.$$

Constructing their membership functions and non-membership functions is the key point in this section.
Therefore, according to the characteristics of IFTS intervals, a more objective method is proposed in this section.
First of all, two rules based on objective analysis are as follows:

a) When x is located in the middle of an interval, namely, $x = (d_{i-1} + d_i)/2$, we define that $\mu_{Ai}((d_{i-1} + d_i)/2) = 1$ and $\gamma_{Ai}((d_{i-1} + d_i)/2) = 0$

b) When x is located on the boundaries of an interval, namely, $x = d_i$, we define that intuitionistic index has the maximum value and

$$\mu_{Ai}(d_i) = \gamma_{Ai}(d_i). \text{ Let } \pi_{Ai}(d_i) = \alpha \ (0 \le \alpha \le 1);$$

then we can get $\mu_{Ai}(d_i) = \gamma_{Ai}(d_i) = (1 - \alpha)/2$

$$c_{\mu i} = c_{\gamma i} = \frac{d_{i-1} + d_i}{2}$$

$$\sigma_{\mu i}^2 = -\frac{(d_{i-1} + d_{\mu i})^2}{2\ln\left(\frac{(1-\alpha)}{2}\right)}$$

$$\sigma_{\gamma i}^2 = -\frac{(d_i + c_{\gamma i})^2}{2\ln\left(1 + \frac{(1-\alpha)}{2}\right)}$$

According to the calculation of $\pi Ai(x)$, it can be easily found that

$\pi Ai(x) + \mu Ai(x) + \gamma Ai(x) = 1$. This completes the proof.

IFTS model is proposed for gold price forecasting

Intuitionistic Fuzzy Multiple Modus Ponens. Let Ai ($i = 1, 2, \ldots, n$) and $A*$ be intuitionistic fuzzy sets in universe U and let Bi ($i = 1, 2, \ldots, n$) and $B*$ be intuitionistic fuzzy sets in universe V.
The generalized multiple modus ponens based on intuitionistic fuzzy relation is that "y is $B*$" can be inferred :

"if x is Ai, then y is Bi" and "x is $A*$."

The reasoning model is as follows: Every rule has a corresponding input-output relation Ri. For Ri, different operators result in different μR and γR, but the reasoning outputs are all the same.

Rules:	IF x is A_1	THEN	y is B_1
	IF x is A_2	THEN	y is B_2
		⋮	
	IF x is A_n	THEN	y is B_n
Input:	IF x is A^*		
Output:			y is B^*

Since it has a better performance and is easier to calculate than other operators.

$$R_i = (A \times B) = \{\langle (x,y), \mu_{R_i}(x,y), \gamma_{R_i}(x,y)\rangle \mid (x,y) \in U \times V\},$$

where,

$$\mu_{R_i}(x,y) = \mu_{A_i}(x) \wedge \mu_{B_i}(x),$$

$$\gamma_{R_i}(x,y) = \gamma_{A_i}(x) \vee \gamma_{B_i}(y).$$

Then, according to the compositional operation of intuitionistic fuzzy rules, we get the total

$$R = \bigcup_{i=1}^{n} R_i$$
$$= \{\langle (x, y), \mu_R(x, y), \gamma_R(x, y)\rangle \mid (x, y) \in U \times V\},$$

where,

$$\mu_R(x, y) = \bigvee_{i=1}^{n} \mu_{R_i}(x, y) = \bigvee_{i=1}^{n} \left(\mu_{A_i}(x) \wedge \mu_{B_i}(y)\right),$$
$$\gamma_R(x, y) = \bigwedge_{i=1}^{n} \gamma_{R_i}(x, y) = \bigwedge_{i=1}^{n} \left(\gamma_{A_i}(x) \vee \gamma_{B_i}(y)\right).$$

The reasoning output is

$$B^* = A^* \circ R,$$

where "∘" is defined as the maximum and minimum operators: "∨" and "∧":

$$\mu_{B^*}(y) = \bigvee_{x \in U} \left(\mu_{A^*}(x) \wedge \mu_R(x, y)\right),$$
$$\gamma_{B^*}(y) = \bigwedge_{x \in U} \left(\gamma_{A^*}(x) \vee \gamma_R(x, y)\right).$$

3.3 Forecast Rules of IFTS Model.

Exchange the positions of historical data and intuitionistic fuzzy sets (i = 1, 2, . . . , r) in the IFTS model; that is, let the historical data be intuitionistic fuzzy sets, noted as

Fi (j = 1, 2, . . . , t), and let Ai be the elements in Fj, and let μAi (x) and γAi (x) be the membership and nonmember ship of Ai to Fj. Then Fj is as follows

$$F_j = \sum_{i=1}^{r} \frac{\langle \mu_{F_i}(x_i), \gamma_{F_i}(x_i)\rangle}{x_i}$$

where.

$$\mu_{F_i}(x_i) = \mu_{A_i}(f_i(t))$$
$$\gamma_{F_i}(x_i) = \gamma_{A_i}(f_i(t))$$

Hence, we apply the intuitionistic fuzzy multiple modus ponens to Ai and Fj. The reasoning model is as follows:

Rules: IF x is F_1 THEN y is F_2

IF x is F_1 THEN y is F_3

.

.

.

IF x is F_i THEN y is F_{j+1}

.

.

.

IF x is F_{t-1} THEN y is F_t

Input: IF x is F_t

Output: y is F^{*}_{t+1}

So, got the membership and non-membership of the output intuitionistic fuzzy set.

3.4 Defuzzification

Defuzzification is the process of obtaining a single number from the output of the aggregated fuzzy set. The gravity algorithm, is using for defuzzification.

The calculation is as follows

$$C = \frac{\int_U C(\boldsymbol{\mu}_F(C) + (1/2)\boldsymbol{\pi}_F(C))\,dc}{\int_U (\boldsymbol{\mu}_F(C) + (1/2)\boldsymbol{\pi}_F(C))\,dc}$$

We compared the performance of the proposed prediction system to the techniques used in previous research to predict the gold price:

- ARIMA
- High-order fluctuation
- Intuitionistic fuzzy time series forecasting model

Performance Analysis

- The performance of the proposed model is then measured using mean square error (MSE), root mean square error (RMSE) and mean absolute error (MAE).
  DATASET
- Collected gold price data from MarketWatch database's monthly prices for COMEX Gold futures during the years 2018 to 2023.

Figure 2

- Define and partition the universe of discourse.
- The gold prices value from year 1918 to 1923 are chosen as historical data to gold price forecast of year 1923(April) the minimum and maximum values are identified as 1232.85 and 2070,. In the historical data, $x$min =32.85 and $x$max = 30, so the universe of discourse is set to U = [1200,2100].

- The universe of discoursed is partitioned into intervals

Table 1

	Interval		Interval
U_1	[1200,1300]	U_6	[1700,1800]
U_2	[1300,1400]	U_7	1800,1900]
U_3	[1400,1500]	U_8	1900,2000
U_4	[1500,1600]	U_9	2000,2100
U_5	[1600,1700]		

Construct intuitionistic fuzzy sets and intuitionistically fuzzify the historical data.

- Corresponding to the 9 intervals, there should be 9 intuitionistic fuzzy sets
- For $\alpha = 0.4$, the parameters are shown in Table 2

Table 2

Intuitionistic fuzzy set	$c_{\mu i}$	$\sigma_{\mu i}$	$c_{\gamma i}$	$\sigma_{\gamma i}$
A_1	1214.5	98.43	1214.5	186.7
A_2	1275.9	321.6	1275.9	582.3
A_3	1303.7	215.7	1303.7	381.4
A_4	1492.3	483.7	1492.3	723.7
A_5	1502.6	173.5	1502.6	267.1
A_6	1669.3	313.9	1669.3	582.7
A_7	1736.5	345.7	1736.5	619.4
A_8	1955.4	192.6	1955.4	312.6
A_9	2057.3	283.6	2057.3	513.7

The membership function, non-membership function, and intuitionistic index function of every intuitionistic fuzzy set are shown in Figures 3, 4, and 5, respectively

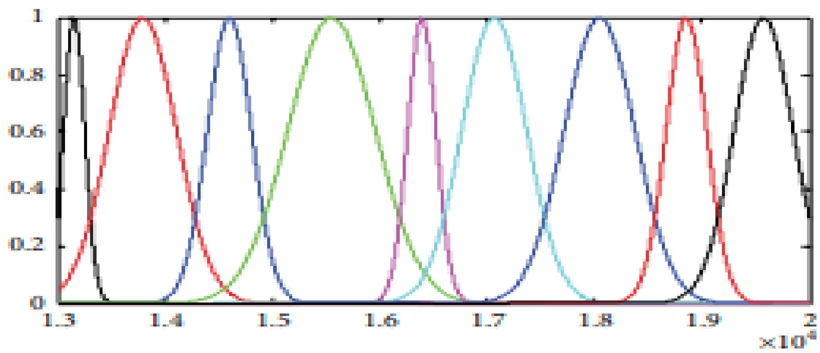

Figure 3: Membership functions

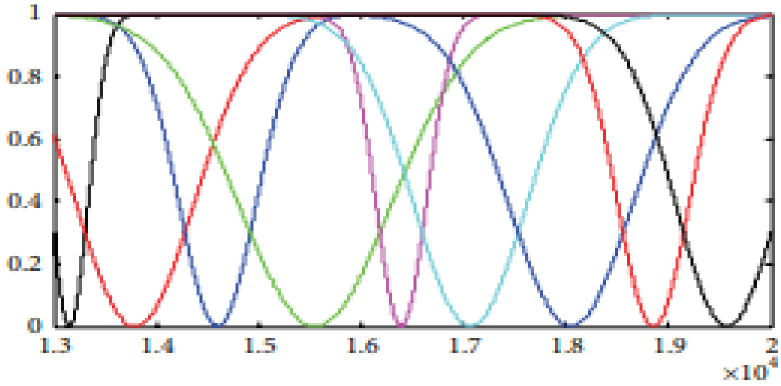

Figure 4: Non-membership functions

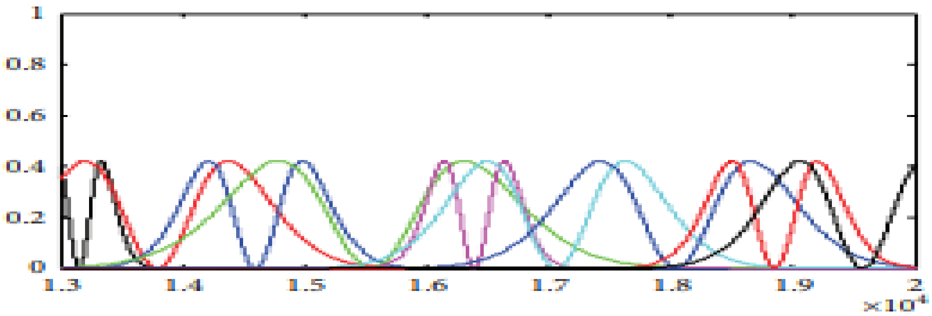

Figure 5: Intuitionistic index functions.

IFTS model is proposed for gold price forecasting

Establish forecast rules and forecast the gold price.

- The gold prices of year 1918 to 1923 can be denoted as $F1$, $F2$,...etc and the reasoning model based on

Rules: IF x is F_1 THEN y is F_2
IF x is F_2 THEN y is F_3
⋮
IF x is F_{20} THEN y is F_{21}
Input: IF x is F_{21}
Output: y is F_{22}^*
Then we get F_{22}^*:

$$= \frac{(0.1)}{A_1} + \frac{(0.1)}{A_2} + \frac{(0.1)}{A_3} + \frac{(0.1)}{A_4} + \frac{(0.1)}{A_5} + \frac{(0,0745)}{A_6} + \frac{(0.637,0.237)}{A_7} + \frac{(0.648,0.218)}{A_8} + \frac{(0.064,0.731)}{A_9}$$

where the membership of F_{22}^* to A_8 is the biggest and the nonmembership is the smallest, so the intuitionistic forecasted result is A_8

Defuzzify and output the forecast result

$$\boldsymbol{C} = \frac{\int_U \boldsymbol{C}(\mathbf{2} + \boldsymbol{exp}(-(\boldsymbol{c} - \mathbf{19456.5})^2/(\mathbf{2} \times \mathbf{197.8^2})) - \boldsymbol{exp}(-(\boldsymbol{c} - \mathbf{19456.5})^2/(\mathbf{2} \times \mathbf{197.8^2})))\boldsymbol{dc}}{\int_U(\mathbf{2} + \boldsymbol{exp}(-(\boldsymbol{c} - \mathbf{19456.5})^2/(\mathbf{2} \times \mathbf{197.8^2})) - \boldsymbol{exp}(-(\boldsymbol{c} - \mathbf{1946.5})^2/(\mathbf{2} \times \mathbf{197.8^2}))) \, \boldsymbol{dc}} = \mathbf{19457}$$

That is to say, the forecasting of year 1993 is 19457

- To test the performance of our model, we use the models of inference as well as ours to forecast every year's, respectively.
- The results are shown in Table 3.
- The models of inference are FTS models, and the model of inference is an IFTS model.
- In inference, there are three kinds of universe partition: 7, 17, and 22 intervals.
- Since there are only 22 historical data, the 17- interval partition and 22-interval partition are not applicable, so we choose the 7-interval partition.
- The mean square error (MSE), root mean square error (RMSE) and mean absolute error (MAE) are exploited to evaluate the performance of every model:

Table 3 presents the actual and forecasted gold prices using the integrated intuitionistic fuzzy time series forecasting model.

Table 3

Month	Actual price	Forecasted price	Month	Actual	Forecasted
1/2018	1343	-	10/2020	1895	1902
2/2018	1317	1367	11/2020	1780	1789
3/2018	1327	1389	12/2020	1895	1902
4/2018	1319	1356	1/2021	1850	1889
5/2018	1304	1334	2/2021	1728	1774
6/2018	1254	1287	3/2021	1715	1754
7/2018	1233	1242	4/2021	1767	1782
8/2018	1206	1223	5/2021	1905	1934
9/2018	1196	1201	6/2021	1771	1789
10/2018	1215	1256	7/2021	1817	1856
11/2018	1226	1298	8/2021	1818	1854
12/2018	1281	1290	9/2021	1757	1782
1/2019	1325	1378	10/2021	1783	1796
2/2019	1316	1378	11/2021	1776	1784
3/2019	1298	1301	12/2021	1828	1852
4/2019	1285	1296	1/2023	1796	1799
5/2019	1311	1337	2/2023	1900	1907
6/2019	1413	1435	3/2023	1954	1978
7/2019	1437	1478	4/2023	1911	1943
8/2019	1529	1554	5/2023	1848	1876
9/2019	1472	1489	6/2023	1807	1834
10/2019	1514	1554	7/2023	1781	1784
11/2019	1472	1489	8/2023	1726	1789
12/2019	1523	1567	9/2023	1672	1679
1/2020	1587	1598	10/2023	1640	1653
2/2020	1642	1678	11/2023	1759	1768
3/2020	1596	1601	12/2023	1826	1856
4/2020	1751	1757	1/2023	1945	1967
5/2020	1800	1813	2/2023	1836	1845
6/2020	1985	1998	3/2023	1986	1993
7/2020	1978	1987	4/2023	-	2002
8/2020	1895	1901			
9/2020	1895	1905			

Forecast results of gold price

Fig 6. The forecast results of every model

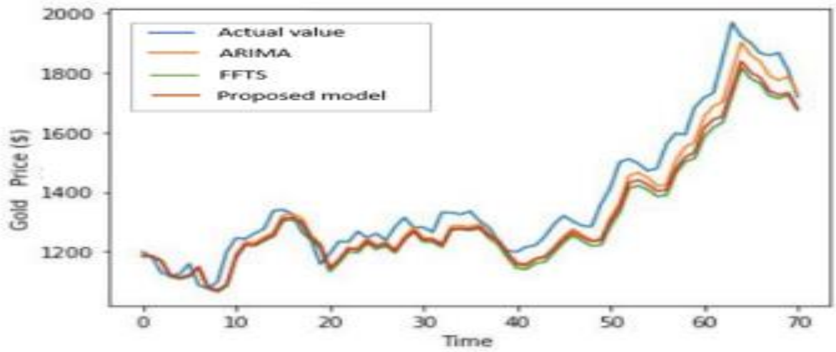

Table 4: Forecast performance of gold price

Method	MSE	RMSE	MAE
ARIMA (Guha 2016)	-	71.635	46.3150
FFTS(Guan 2018)	93.63	96.76	79.54
IFTS	87.15	68.91	43.16

- The results in Tables 3 and 4 indicate that our model can not only reach the forecast goal but also achieve a better result than the other tested models.
- For comparison, we also applied the models of reference [Guha et al. (2016),(Guan et al. (2018)], to forecast gold prices at the same time.
- The forecast results of every model are shown in Table 3 and Figure 6.
- Table 4 indicates that the mean square error (MSE), root mean square error (RMSE) and mean absolute error (MAE) of proposed model are both smaller than the other models.
- Therefore, our experiments indicate that the IFTS model proposed in this paper could effectively increase forecast accuracy

4. CONCLUSION

The results show that Intuitionistic fuzzy time series model is outperforms to the other models. Therefore, our experiments indicate that the IFTS model proposed in this paper could effectively increase forecast accuracy

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