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Estimation of crude oil price using unscented kalman filter

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Abstract. The stock market and commodity relation is one of the most attractive issues for investors. A problem in one stock market can affect another advertise cost files. Raw petroleum Prices are affected by political conditions and factors related to the weather, and oil has moreoverplayed a key jobin the world economy despite the fact that its inclination changes from time to time. The instability of oil costs can be thought about by assessing world raw petroleum costs, thereby prediction can made to see at the point at the point when world oil costs fall or rise and to decide arrangements on the buy and utilization of unrefined petroleum. In this study methods of estimating the crude oil prices were applied to decide government strategies regarding the world crude oil. The purpose of this examination was to assess the prices of raw petroleum by applying the Unscented Kalman Filter (UKF) method and Kalman Filter (KF) technique. The simulations results suggested that the KF strategy has a high precision of not exactly 3% and the KF technique has precision of not exactly 7%.

1. Introduction

In globalized trading, commodity trading depends on not only the commodity but also the role the companies plays in production and distribution. One of the steps that an oil company make has apparent effects on the world oil prices is related to oil inventory and oil drilling [1].Nowadays, the world's oil supply is around 1-2 million barrels, greater than its demand. This is because it is not absorbed enough by consumption/ Thus, its excess shall be stored somewhere. The allocation of oil to storage is known as inventory. The excessive oil supply is stored in inventory as a preparation when someday production decreases, or demand increases.

The problem is that there is limited space available. Therefore, the higher the amount of inventory, the greater the possibility that world oil prices will fall, because the exessive oil amount cannot be adequately stored in the inventory as expected, then it becomes abundant in the market.

The strategy oil companies adopt in production also has a major effect on the world oil price trends. For instance, the use of fracking techniques to explore shale oil in the US and the practice of "fracklog" ("storing oil" at exploration sites) which has the potential to weaken the world oil prices due to abundant production and inventory.No less influential is the condition of the companies in such industry themselves. Say a mass bankruptcy occurs because the world oil prices are too low, and this automatically cuts supply and causes a rise in prices.

To observe the ups and downs of oil prices, an effort shall be made by making estimation of world raw petroleum costs, so oil entrepreneurs can anticipate at the point when world oil costs fall or rise and decidestrategies in the production also, utilization of oil. Numerous examinations on estimation have been conducted in every single logical field, includin blood stock estimation, stock price estimation

[2,3], company profit estimation [4], steam drum temperature estimation [5], AUV trajectory estimation [6,7], ASV trajectory estimation [8] and missile trajectories estimation [9]. So, this paper applies the technique for assessing world unrefined petroleum costs, namely the Unscented Kalman Filter (UKF) to determine the right decision the oil entrepreneurs shall make regarding world crude oil.

2. Methods

The calculation of Kalman Filter (KF) can be seen [4]:

1. Model framework and estimation model.

$$x_{k+1} = A_k x_k + B_k u_k + G_k w_k \quad (1)$$

$$z_k = H_k x_k + v_k \quad (2)$$

$$x_0 \sim N(\bar{x}_0, P_{x_0});\ w_k \sim N(0, Q_k);\ v_k \sim N(0, R_k) \quad (3)$$

2. Inisialitation

$$\hat{x}_0 = \bar{x}_0 \quad (4)$$

$$p_0 = p_{x_0} \quad (5)$$

3. Time Update

$$\text{Estimation}: \hat{x}_{k+1}^{-} = A_k \hat{x} + B_k u_k \quad (6)$$

$$\text{Error } covariance: P_k^{-} = A_k P_k A_k^T + G_k Q_k G_k^T \quad (7)$$

4. Measurement Update

$$\text{Kalman gain}: K_{k+1} = P_{k+1}^T H_{k+1}^T \left(H_{k+1} P_{k+1}^{-} H_{k+1}^T + R_{k+1}\right)^{-1} \quad (8)$$

$$\text{Estimation}: \hat{x}_{k+1} = \hat{x}_{k+1}^{-} + K_{k+1}\left(z_{k+1} - H_{k+1}\hat{x}_{k+1}^{-}\right) \quad (9)$$

$$\text{Error covariance } P_{k+1} = \left[I - K_{k+1}H_{k+1}\right]P_{k+1}^{-} \quad (10)$$

And algorithm of Unscented Kalman Filter is writen as follows [10]:

- *Initiation at k = 0*:

$$\hat{x}_0 = E[x_0]$$

$$\mathrm{P}_{\mathrm{x}_0} = \mathrm{E}[(\mathrm{x}_0 - \hat{\mathrm{x}}_0)(\mathrm{x}_0 - \hat{\mathrm{x}}_0)^{\mathrm{T}}]$$

$$\hat{x}_0^a = E[x^a] = E\left[\hat{x}_0{}^T \ 0 \ 0\right]^T$$

$$P_0^a = E[(x_0^a - \hat{x}_0)(x_0^a - \hat{x}_0)^T] = \begin{bmatrix} P_x & 0 & 0 \\ 0 & P_v & 0 \\ 0 & 0 & P_n \end{bmatrix} \quad (11)$$

For k = 1,2,3,...,∞:

1) Count sigma point

$$X_{k-1}^a = \left[\hat{x}_{k-1}^a \quad \hat{x}_{k-1}^a + \gamma\sqrt{P_{k-1}} \quad \hat{x}_{k-1}^a - \gamma\sqrt{P_{k-1}}\right]$$

Dimana:

$$\gamma = \sqrt{L + \lambda}$$

$$\lambda = \alpha^2(L + \kappa) - L \quad (12)$$

2) Time-update (prediction stage)

$$X_{k|k-1}^{x} = f(X_{k-1}^{x}, X_{k-1}^{v})$$
$$\hat{x}_k^- = \sum_{i=0}^{2L} W_i^{(m)} X_{i,k|k-1}^{x}$$
$$P_{x_k}^- = \sum_{i=0}^{2L} W_i^{(c)} \left(X_{i,k|k-1}^{x} - \hat{x}_k^-\right)\left(X_{i,k|k-1}^{x} - \hat{x}_k^-\right)^T$$
$$Z_{k|k-1} = H(X_{k|k-1}^{x}, X_{k-1}^{n})$$
$$\hat{z}_k^- = \sum_{i=0}^{2L} W_i^{(m)} Z_{i,k|k-1} \quad (13)$$

3) Measurement update (correction stage):

$$P_{\bar{z}_k,\bar{z}_k} = \sum_{i=0}^{2L} W_i^{(c)} \left(Z_{i,k|k-1} - \hat{z}_k^-\right)\left(Z_{i,k|k-1} - \hat{z}_k^-\right)^T$$
$$P_{x_k,z_k} = \sum_{i=0}^{2L} W_i^{(c)} \left(X_{i,k|k-1}^{x} - \hat{x}_k^-\right)\left(Z_{i,k|k-1} - \hat{z}_k^-\right)^T$$
$$K_k = P_{x_k,z_k} P_{\bar{z}_k,\bar{z}_k}^{-1}$$
$$\hat{x}_k = \hat{x}_k^- + K_k(z_k - \hat{z}_k^-)$$
$$P_{x_k} = P_{x_k}^- - K_k P_{\bar{z}_k} \mathrm{K}_k^T \quad (14)$$

3. Simulation Result

This simulation of the KF and UKF calculations application to the raw petroleum capacities gained from numerical programmingsimulatioindicated the crude oil data as displayed in Table 1. The results of the simulation were assessed and contrasted with the set up crude oil capacities, and the raw petroleum value capacities are in condition (15) as follows:

$$f(x) = 61{,}5x^2 - 782{,}7x + 5112$$
$$f'(x) = 123x - 782{,}7 \quad (15)$$

Sincethe framework requires discretation, the unrefined petroleum capacities model in condition (15) is discreted applying the limited contrast strategy. The difference in state variable in regard to the time is approximated by forward plan of limited distinction. So, we get the accompanying.

$$f' = \frac{df}{dt} \approx \frac{f_{k+1} - f_k}{\Delta t} \quad (16)$$

from conditions(15) and (16), the adjusted the oil rough capacities model in (17) is acquired as follows:

$$f_{k+1} = (123x_k - 782{,}7)\Delta t \quad (17)$$

Information of the World Crude Oil Prices are as per the following:

Table 1.Information of the World Crude Oil Prices

No	Trade Date	Price
1	1 Jun 2016	56.22
2	2 Jun 2016	52.49
3	4 Jun 2016	52.75
4	5 Jun 2016	53.18
5	6 Jun 2016	51.96
6	7 Jun 2016	51,92
7	8 Jun 2016	53.55
8	10 Jun 2016	53.21

9	11 Jun 2016	52.37
10	12 Jun 2016	52.48
11	13 Jun 2016	51.08
12	15 Jun 2016	52.42
13	16 Jun 2016	52.75
14	17 Jun 2016	53.18
15	18 Jun 2016	52.88
16	19 Jun 2016	53.78
17	21 Jun 2016	53.17
18	22 Jun 2016	52.79
19	23 Jun 2016	53.86
20	24 Jun 2016	52.93
21	25 Jun 2016	53.20
22	27 Jun 2016	54.11
23	28 Jun 2016	56.01
24	29 Jun 2016	51.55
25	30 Jun 2016	52.34
26	1 Jul 2016	53.46
27	2 Jul 2016	53.86
28	3 Jul 2016	52.93
29	5 Jul 2016	54.60
30	6 Jul 2016	54.62
31	7 Jul 2016	56.36
32	9 Jul 2016	54.40
33	10 Jul 2016	53.06
34	11 Jul 2016	54.59
35	12 Jul 2016	53.45
36	13 Jul 2016	52.99
37	14 Jul 2016	53.15
38	16 Jul 2016	54.01
39	17 Jul 2016	53.83
40	18 Jul 2016	52.61
41	19 Jul 2016	53.33
42	21 Jul 2016	53.20
43	22 Jul 2016	53.14
44	23 Jul 2016	48.49
45	24 Jul 2016	47.86
46	25 Jul 2016	48.78
47	26 Jul 2016	48.22
48	28 Jul 2016	49.04
49	29 Jul 2016	49.73
50	31 Jul 2016	57.5
51	2 Aug 2016	50.24
52	4 Aug 2016	51.03
53	6 Aug 2016	51.15
54	7 Aug 2016	51.70
55	8 Aug 2016	52.59
56	9 Aug 2016	53.08
57	11 Aug 2016	53.67

58	12 Aug 2016	53.22
59	13 Aug 2016	53.33
60	14 Aug 2016	52.37

In this examination a recreation was completed by applying the KF and UKF calculations to the capacity of raw petroleum. The recreation results were assessed by looking at the genuine conditions in the field with those of the aftereffects of KF and UKF gauges. This reenactment utilized$\Delta t = 0.1$ and 300 emphasess and produced300, 400 and 500 iterations. Figure 1 is a correlation of the assessed aftereffects of KF and those ofKF and those of UKF which created 300 iterations. Figure 2 is the aftereffect of the recreation of the KF and UKF strategiesusing 400 iterations.Figure 3 is a recreation of the KF and UKF strategiesusing 500 iterations.

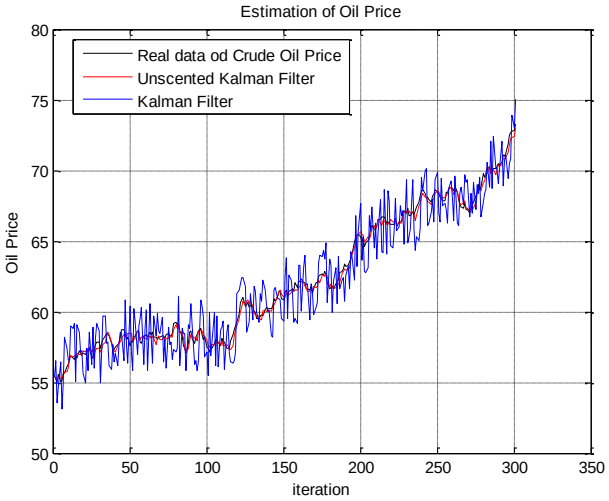

Figure 1. Estimation of unrefined petroleum costs utilizing KF and UKF strategy with 100 cycles

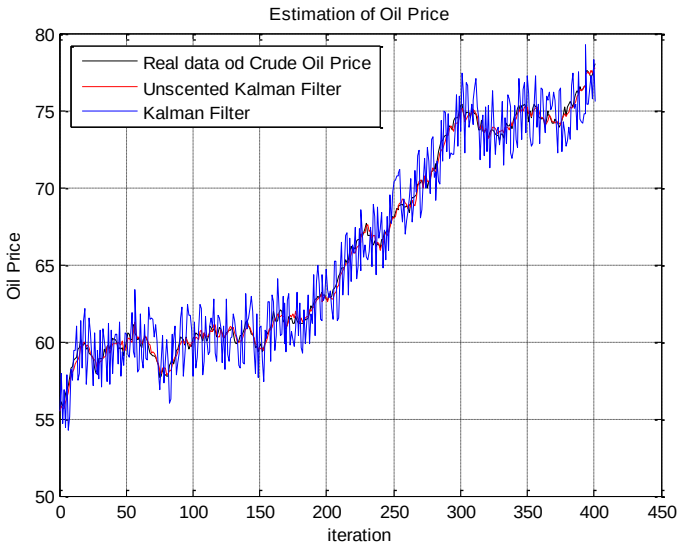

Figure 2. Estimation of unrefined petroleum costs utilizing UKF and KF strategy with 400 cycles

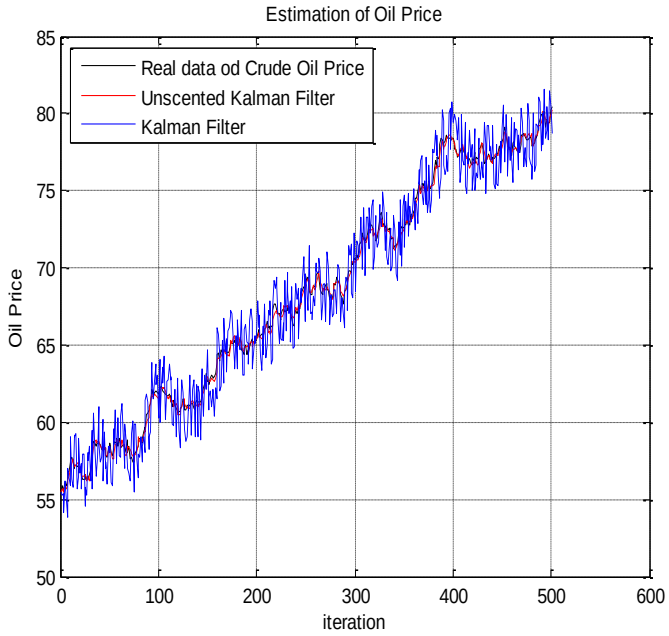

Figure 3. Estimation of raw petroleum costs utilizing UKF and KF technique with 500 cycles

Figure 1 shows that the evaluated unrefined petroleum cost has an example that is nearly equivalent to the cost of genuine raw petroleum, where the assessed raw petroleum value utilizing theUKF technique has high exactness with a mistake of not exactly 3%, and RMSE of 0.2779. In any case, the estimation results utilizing the KF technique have a significant mistake of around 12% with RMSE of 0.7916. In Figure 2 and Figure 3, apparently theUKF strategy has higher precision than the KF technique, where the exactness of the UKF strategy is near97%, while the KF strategy has higher precision than the KF technique because of a number of troupes created. In Table 2, apparently the UKF technique by creating 500 iterationshas higher precision than that by producing 400 and 300 iterations, since for this situation the quantity of cyclescreated likewise influences exactness.

Table 2. Correlation the estimations of RMSE by the utilization of the KF and UKF based on300, 400 and 500 Cycles

	KF vs UKF with 300 iterations		**KF vs UKF with 400 iterations**		**KF vs UKF with 500 iterations**	
	KF	**UKF**	**KF**	**UKF**	**KF**	**UKF**
crude oil prices	0.9889	0.2950	0.8712	0.2866	0.7916	0.2779
Simulation Time	3.4791 s	3.6623 s	5.915 s	6.1234 s	7.3811 s	7.9236 s

By and large the KF and UKF technique can be effectrively utilized as a strategy to assess unrefined petroleum costs with genuinely great precision. The techniqueUKF has higher precision than the KF technique, on the grounds that there is a procedure of producing various unscented at the phase of remedy in order to make progressively exact evaluations. Be that as it may, the shortcoming of the UKF technique takes longer calculation time than the KF strategy.

4. Conclusion

In view of the aftereffects of the reenactment examination, as a rule the KF andUKF technique can be effectrively utilized as a strategy to appraise unrefined petroleum costs with genuinely great exactness.

It could be presumed that the KF and UKF strategies could be applied to assess unrefined petroleum capacities with high exactness for 300, 400 or 500 iterations. The subsequent blunders were under 2% for UKF strategy and under 8% for KF technique.
Open problem. How to implemented Fuzzy Kalman Filter (FKF) for estimation of crude oil price.

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