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Estimation of Packed Red Cells (PRC) in Bojonegoro blood bank using Modified Kalman Filter

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Abstract. Blood Transfusion Unit (UTD) as a blood supply provider is required to meet the demand for blood, but in reality, the blood stock does not always meet the blood demand. The blood type stocks in the Blood Transfusion Unit (UTD) relies on blood donors voluntarily donating their blood. Red blood cells only have a life span of 35 days as of the blood donation date. If overdue the blood cannot be used for transfusion. Fulfillment of the availability of blood is a very important thing. On one hand, too much blood stock results in significant losses, such as expiration. On the other hand, too low blood stock makes the people's blood needs unfulfilled. Therefore, this paper is an effort to estimate the blood supply at Indonesian Red Cross Bojonegoro by using the Modified Kalman Filter method. The Modified Kalman Filter is a comparison of two Kalman Filter development methods, those are Extended Kalman Filter (EKF) and Fuzzy Kalman Filter (FKF). The simulation results showed that the EKF method was accurate than the FKF method, with an error of 3 % generated by the EKF and that of 9% by the FKF.

1. Introduction

Blood Transfusion Unit is one of the most important parts of the Indonesian Red Cross organization. This unit functions to receive blood donors, store blood, and distribute it to those in need of it. The Indonesian Red Cross Blood Transfusion Unit (UTD-PMI) is located in every district in Indonesia. Currently, throughout Indonesia there are 256 units (UTD-PMI) to serve all hospital needs, both government-owned and private ones. Due to its strategic role as a blood supply management, UTD-PMI must have accurate and reliable data management. However, only a few of all units (UTD-PMI) have had good management of blood supply and demand [1].

To meet the demand for blood from hospitals for blood transfusion purposes, the Surabaya City PMI Blood Donor Unit sends blood suitable with the patient's blood (already through a cross match reaction). Regarding the patient's identity and the recording of the blood number sent, it must be clear and in accordance with the blood request form from hospital [2]. The request form for blood from the hospital must include identity of patient, diagnosis of disease, indication of transfusion, quantity and type of blood/blood components requested and signed by the doctor with hospital stamp [3].

The blood distribution to hospitals by the PMI Blood Donor Unit is a pick-up system if it is carried out in the same PMI area concerned. Therefore, the demand for blood by recipients to the hospital or PMI Blood Donor Unit may take place before the hospital makes a blood request to the PMI Blood Donor Unit.



The hospital made an offer to the recipient or his family, stating that the patient is in need of blood, and for that purpose the blood for the patient is from either the PMI Blood Donor Unit or the family. Beside giving the offer, the hospital also explains that if the blood comes from the family, it will take a long process [4]. PMI has an obligation to assist in the establishment of a Hospital Blood Bank under Hospital management. One of the tasks of the blood bank is to plan blood needs and daily or weekly monitor blood supplies at the hospital concerned.

One way to lower the risk of excess and shortage of blood supply and demand is by applying an estimation algorithm to determine the future blood supply. Several cases, beside those in the health sector, applied estimation algorithms, including the application of estimation methods in the economic field, namely to estimate the stock [5] and smartphone price in market [6], and that in the technical field, to estimate steam drum water height [7], as well as those utilized to estimate the missile position [8] and AUV [9,10], widely applied to determine the trajectory for the vehicle to follow. Those cases all utilized an estimation algorithm, and in this study the methods used in estimating blood supply in hospital blood bank were Extended Kalman Filter (EKF) and Fuzzy Kalman Filter (FKF), serving as a chart for the hospital to take into consideration in the blood supply and demand management.

2. PRC Blood Data

Packed Red Cell (PRC) is a blood component obtained after most of the plasma is separated from whole blood by various methods and has a hematocrit value of 80%. Packed Red Cells are stored at 2-6 °C for 21-42 days depending on the anticoagulant-preservative solution used. The data of the PRC is shown as follows:

Table 1. Blood data of PRC type in Bojonegoro Blood Bank.

Blood Data of PRC Type												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2013	593	629	608	515	495	822	626	584	1133	848	734	497
2014	1015	928	1127	1138	1027	957	968	1046	1107	1203	1193	1160
2015	1319	1112	1371	1252	1272	1224	1322	1279	1154	1398	1218	1382
2016	1477	1456	1392	1426	1452	1554	1572	1603	1415	1415	1439	1157
2017	1540	1411	1510	1540	1575	1506	1569	1506	1421	1845	1663	1565
2018	1174	1458	1479	1424	1350	1215	1487	1552	1287	1385	1456	1327
2019	1525	1434	1435	1508	1493	1394	1624	1848	1314	1530	1571	1390

3. Extended and Fuzzy Kalman Filter Algorithm

The algorithm of the EKF and FKF algorithms had 3 stages, that is, the initialization process, the prediction stage, and the correction stage. Before the initialization process, the system modeling was first made. For the FKF method, the fuzzy logic was implemented at both of the prediction and correction stages in the Kalman Filter algorithm. The Extended Kalman Filter algorithm can be seen in Figure 1.

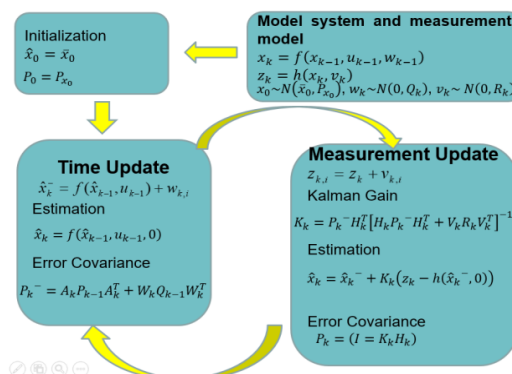


Figure 1. Extended kalman filter algorithm [11].

Fuzzy Kalman Filter is an estimation method that combines the fuzzy set with the Kalman Filter [12]. We generate the variable state of PRC Blood using the Fuzzy set, and the Kalman Filter is applied to estimate that variable state. Lotfi A.Zahde is the person who first introduced the fuzzy set as a mathematical way to represent inaccuracies. If S is a collection of objects denoted by s , then the fuzzy set E is a set of sequential pairs that can be denoted as follows:

$$E = \{(s, \mu E(s)) | s \in S\}$$

4. Results and Discussion

The application of the EKF and Fuzzy KF methods to the functions generated uses Mathematica software in Table 1. Here are the functions of PRC blood:

$$\begin{aligned} f(x) &= -0.260256x^2 + 32.1599x - 529.217 \\ f'(x) &= -0.520512x + 32.1599 \end{aligned} \tag{1}$$

With x is month

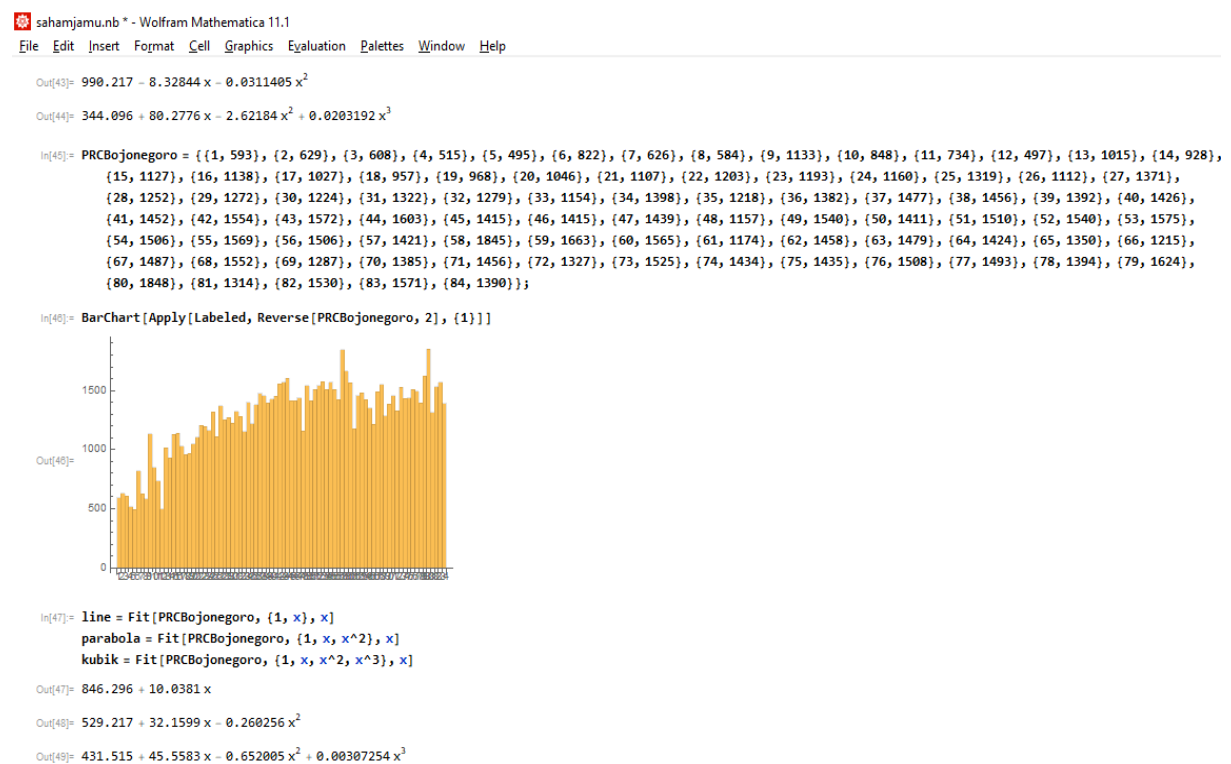


Figure 2. Simulation PRC blood data in Bojonegoro Blood Bank using mathematica software.

From equation (1), the function of PRC blood in Bojonegoro blood bank is discretized through a discretization process so that equation (2) is obtained.

$$f_{k+1} = (-0.520512x_k + 32.1599)\Delta t \tag{2}$$

The application of the EKF and FKF algorithms had 3 stages, that is, the initialization process, the prediction stage, and the correction stage. Before the initialization process, the system modeling was first made. For the FKF method, the fuzzy logic was implemented at both of the prediction and correction stages in the Kalman Filter algorithm. Then it was followed by stating substituting equation (2) already in the form of a discrete model used as a platform to estimate. This paper aimed to compare the results of the numerical computation of the EKF and FKF methods by using 100, 200 and 300 iterations, which can be described by the three simulation results in Figures 3 – 5.

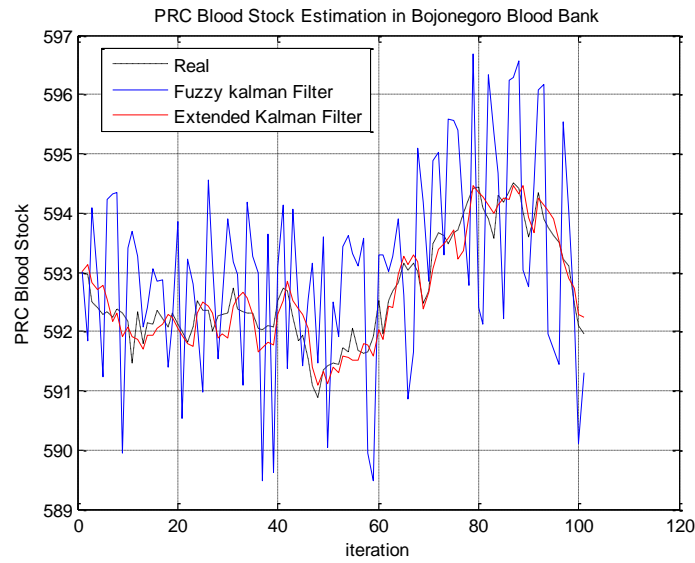


Figure 3. PRC blood Estimation using EKF and FKF methods using 100 iteration.

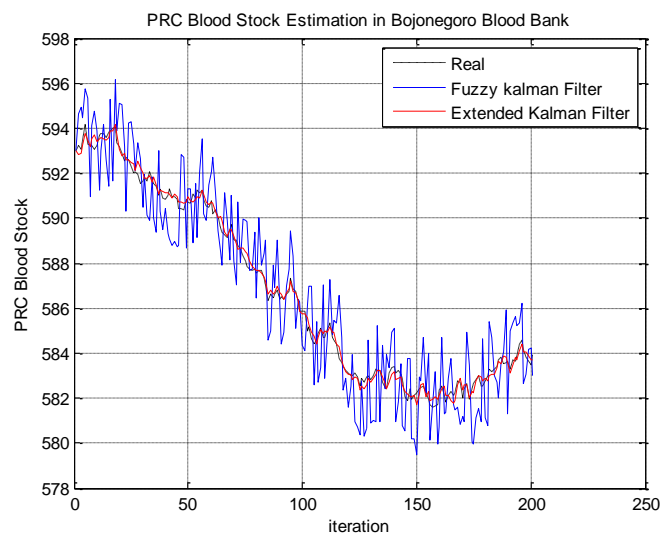


Figure 4. PRC blood Estimation using EKF and FKF methods using 200 iteration.

Based on the simulation results and discussion above, it can be said that Figures 3, 4 and figure 5 show that the results of the PRC blood estimation at PMI Bojonegoro by the EKF method has a small error of about 4% and an accuracy of above 95%, but the FKE generated a bigger error, than that by the FKF, of about 17-24%.

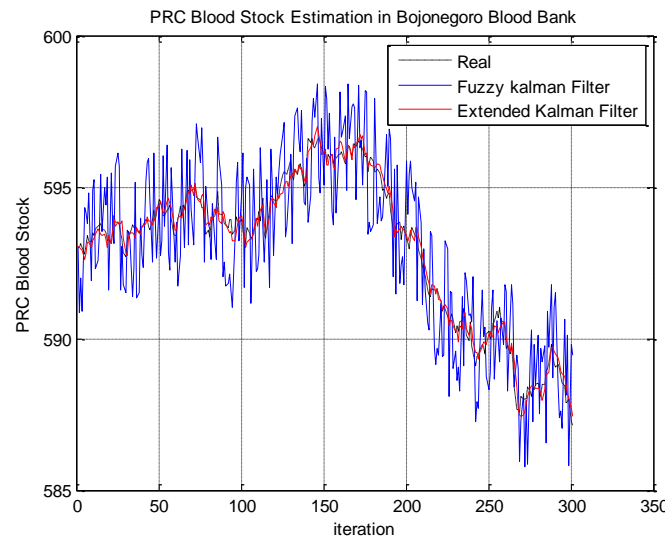


Figure 5. PRC blood Estimation using EKF and FKF methods using 100 iteration.

From the discussion above, it can be said that Figure 3, 4, and 5 show that the results of the Function of PRC blood estimation by the EKF method indicate a small error of about 3%, but those by the H-infinity method show a greater error than that of FKF, that is around 9%.

Table 2. Value of RMSE by the EKF and FKF based on 100, 200 and 300 iteration.

	100 iteration		200 iteration		300 iteration	
	EKF	FKF	EKF	FKF	EKF	FKF
RMSE	0.014589	0,1893	0.0125	0,1791	0.01118	0,1562
Simulation Time	5.213 s	6.78 s	8.592 s	9.824 s	11.359 s	13.012 s

Overall, the EKF method was effectively used for the PRC blood supply estimation at PMI Bojonegoro, while the FKF needs investigating again in combining the two algorithms because it had a fairly big error of above 9-10%. so with the effective implementation of the EKF method as the blood supply and demand estimation, it is expected to effectively support the management of blood distribution at PMI Bojonegoro.

5. Conclusion

Based on the results of the discussion analysis, EKF method can be used as a method to estimate mathematics function of Packed Red Cell (PRC) bloodstock with excellent accuracy and errors of less than 3%, but FKF has errors of 9%. Based on the simulation results above, it is likely that both methods can also be used to estimate other type of bloodstock function, so it can support the work of Bojonegoro blood bank management

Acknowledgement

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