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Estimation of Whole Blood(WB) and Anti-Hemophiliate Factor using Extended Kalman Filter in PMI Surabaya

A Muhith[1], T Herlambang[2], M Y Anshori[3], R Rizqina[3], D Rahmalia[4], Hermanto[5]
[1] Nursing science Department – University of Nahdlatul Ulama Surabaya (UNUSA)
[2] Information System Department – University of Nahdlatul Ulama Surabaya (UNUSA)
[3] Management Department – University of Nahdlatul Ulama Surabaya (UNUSA)
[4] Mathematics Department – University of Islam Darul Ulum Lamongan
[5] Management Department – University of PancaMarga

Email: teguh@unusa.ac.id

Abstract. Every hospital is required to have a Hospital Blood Bank (HBB), a service unit of the hospital responsible for the availability of blood for safe transfusion, of high quality and sufficient to support health services in the hospital and other health care centers. PMI (Indonesian Red Cross) continues to campaign for blood donations as part of a lifestyle (lifestyle). Every year, PMI set its targets of up to 4.5 million blood bags to meet the national blood needs, adjusted to the standards of the International Health Institute (WHO), which is 2% of the population for each day. With a continuous campaign by PMI, the stability of blood stock and distribution on target must be maintained, and the importance of blood distribution both blood coming from blood donors and blood distributed to PMI or other regional hospitals must be taken into account, therefore a software is required to estimate blood stock.for the blood banks. In this paper an estimation of Whole Blood (WB) and Anti-Hemophiliate Factor (AHF) blood demand was made at PMI Surabaya. Estimation is made because a problem can sometimes be solved by using the previous information or data related to the problem. One estimation method used was Extended Kalman Filter (EKF), an estimation method with a fairly high degree of accuracy. Based on the simulation results, a numerical study was obtained based on the number of iterations, and that with 350 iterations showed a higher accuracy than those with 250 and 150 iterations. The accuracy reached was within the range of 95-98 %.

1. Introduction

Every hospital is required to have a Hospital Blood Bank (HBB), a service unit in the hospital responsible for the availability of blood for safe transfusion, of high quality and sufficient to support health services in hospitals and other health care centers. (Minister of Health Regulation 83/2014, Chapter III Article 40). HBB is a service unit established by the Hospital Director and can be part of a laboratory in a hospital.

Currently Indonesia still lacks 500 thousand bags of blood. According to WHO the minimum blood requirement in Indonesia shall be 2% of the population or around 5.1 million bags per year. In fact there are currently only 4.5 million bags out of 3, 05 million donors. Based on this, the Minister of Health in 2014-2019, Prof. Dr. dr. Nila F Moeloek, Sp. M (K) hopes that the community will be more involved and become donors, therefore PMI always conducts blood donor activities as often as possible by involving all elements of the society.

With the enactment of the Permenkes 83/2014, the role of hospitals having HBB is increasingly clear, especially in terms of the duties and responsibilities between HBB and UTD, previously unclear. Now by Permenkes (Health Minister Regulations) it has been emphasized that HBB is a hospital service integrated with UTD with clear duties and responsibilities set up, supported by buildings, facilities and infrastructure, equipment and specific personnels, including HR qualifications and job-description as well as the strength of the network of transfusion services between providers and health services, which up to now, has only covered the related institutions without involving the health department (SW) [1]. PMI continues to campaign for blood donations as part of a lifestyle. Every year, PMI sets a target of up to 4.5 million blood bags to meet the national blood needs, as adjusted to the standards of the International Health Institute (WHO), which is 2% of the population for each day.

With a continuous campaign by PMI, the stability of blood stock and distribution on target shall be maintained, and the importance of blood distribution both blood coming from blood donors and blood distributed to PMI or other regional hospitals shall be taken into consideration. Therefore, a software is needed to estimate blood stock for the blood banks. Many studies on estimation are carried out in all scientific fields, including estimation of stock price and profit company [2,3], steam drum water level [4], estimation of AUV trajectory and ASV position [5,6,7], and estimation of missile trajectories [8].

This paper examined the estimation of blood demand for Whole Blood (WB) and Anti-Hemophiliate Factor (AHF) types for the blood banks. Estimation should be made because a problem can sometimes be solved by using the previous information or data related to the problem with a fairly small error. So with the estimation of blood stock, it is expected to reduce errors in the distribution of blood in various regions or hospitals.

2. Blood Data of *Whole Blood* (WB) and Anti-Hemophiliate Factor (AHF)

The data of Whole Blood (WB) and Anti-Hemophiliate Factor (AHF) is shown as follows:

Table 1. Blood Data of WB type

	Data of WB											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2013	1018	1062	1083	1076	1222	1053	1007	1031	1039	1023	979	1052
2014	1103	953	972	812	872	906	871	1085	897	859	818	744
2015	890	865	911	797	787	687	643	801	730	686	666	723
2016	803	659	653	629	666	599	595	576	629	557	500	504
2017	579	611	675	583	637	488	647	684	581	715	749	612
2018	688	679	640	591	725	759	622	730	676	666	675	599

Table 2. Blood Data of AHF type

	Data of AHF											
	Jan	**Feb**	**Mar**	**April**	**Mei**	**Juni**	**Juli**	**Agust**	**Sep**	**Okt**	**Nov**	**Des**
2013	0	10	3	11	4	0	0	11	26	22	4	29
2014	2	0	0	13	0	0	8	6	0	11	5	18
2015	35	0	49	28	14	3	14	22	15	4	4	18
2016	37	3	5	0	4	3	4	0	0	13	9	2
2017	13	0	8	2	10	6	22	0	4	12	7	0

3. Extended Kalman Filter

The Extended Kalman Filter (EKF) algorithm can be seen [9]:

Model system and measurement model

$$x_k = f(x_{k-1}, u_{k-1}, w_{k-1}) \quad (1)$$

$$z_k = h(x_k, v_k) \quad (2)$$

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

1. Initialization

$\hat{x}_0 = \bar{x}_0$
$P_0 = P_{x_0}$

2. Time Update
   Estimation: $\hat{x}_k = f(\hat{x}_{k-1}, u_{k-1}, 0)$ (4)
   Error covariance: $P_k^{-} = A_k P_{k-1} A_k^T + W_k Q_{k-1} W_k^T$ (5)
3. Measurement Update
   Kalman Gain: $K_k = P_k^{-} H_k^T \left[H_k P_k^{-} H_k^T + V_k R_k V_k^T \right]^{-1}$ (6)

Estimation :$\hat{x}_k = \hat{x}_k^{-} + K_k\left(z_k - h(\hat{x}_k^{-}, 0)\right)$ (7)
Error covariance: $P_k = (I = K_k H_k) P_k^{-}$ (8)

4. Simulation Result

From the blood data of WB and AHF types in Table 1 and 2, a mathematical function was obtained for the blood supply of WB and AHF types using Mathematica software. The Mathematica software simulation resulted in a function of WB and AHF as follows:

$f_{wb}(x) = 1025.13 - 1.3789x - 0.371\, x^2$
$f'_{wb}(x) = -1.3789 - 0.742\, x$ (9)
$f_{ahf}(x) = 1548 - 3{,}137x + 0.869\, x^2$
$f'_{ahf}(x) = -3{,}128 + 1{,}738\, x$ (10)

from equations (9) and (10), the modified WB and AHF blood stock function model in (9) and (10) is discreted using the finite difference method and obtained as follows:

$$f_{wb\,k+1} = (-1.3789 - 0.742 x_k)\Delta t$$
$$f_{tc\,k+1} = (-3{,}128 + 1{,}7382\ \ x_k)\Delta t$$

After the function had been obtained it was simulated with the Matlab software. In this paper the simulation was done by using the Extended Kalman Filter (EKF) algorithm to the function of blood stock of Whole Blood (WB) and Anti-Hemophiliate Factor (AHF) type. The evaluation of the simulation results was done by comparing the real conditions in the field to the estimation results by the EKF application. This simulation used $\Delta t = 0{,}1$ and 150, 250, and 350 iteration.

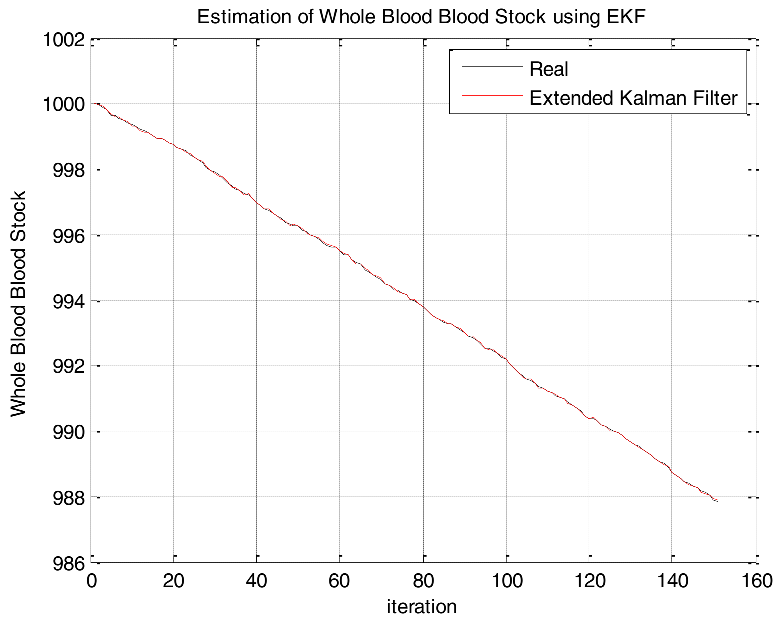

Figure 1. Estimation of WB Blood Stock using EKF method with 150 iterations

Figure 1-3 shows the Whole Blood (WB) stock estimation results by the application of the EKF method using 150, 250, and 350 iteration. Figures 1, 2 and 3 show that the estimation results of WB blood stock had high accuracy with an error of less than 2%, indicating that the estimation of the WB stock declined using either estimation of 150, 250, or 350 iterations. So it could be taken into consideration by PMI to get blood donors to avoid the shortage of blood stock of WB type.

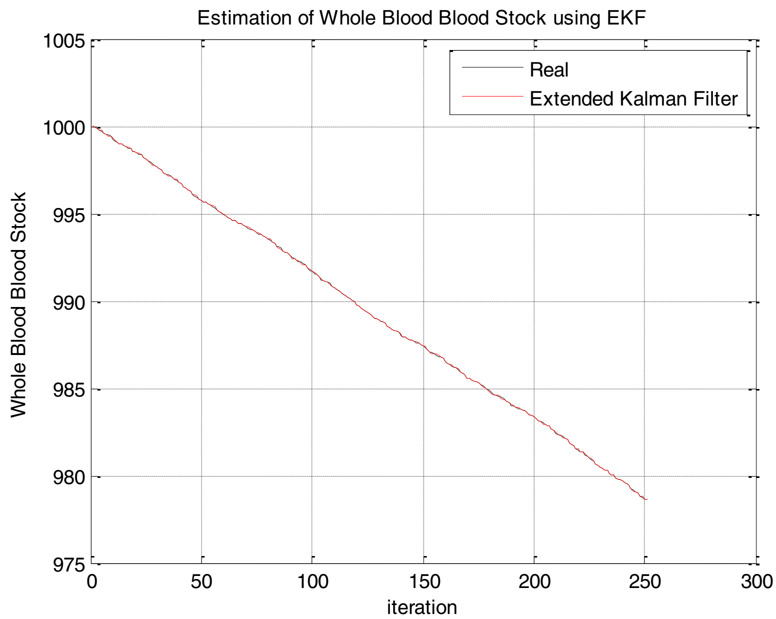

Figure 2. Estimation of WB Blood Stock using EKF method with 250 iterations

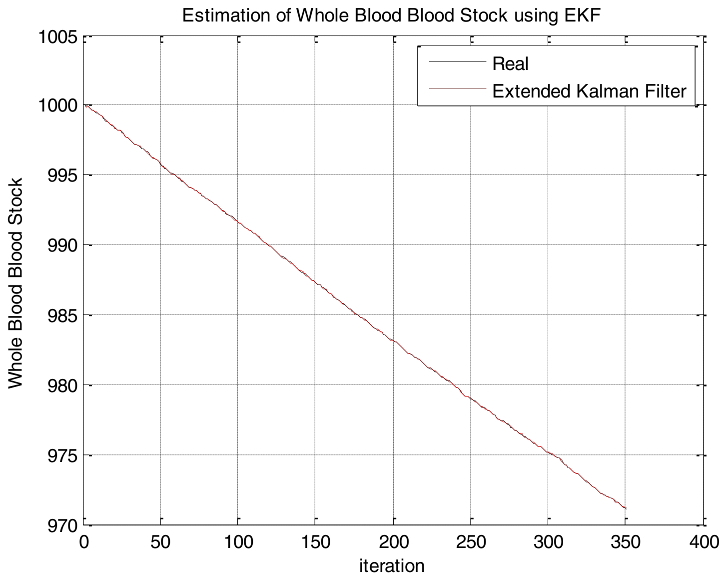

Figure 3. Estimation of WB Blood Stock using EKF method with 350 iterations

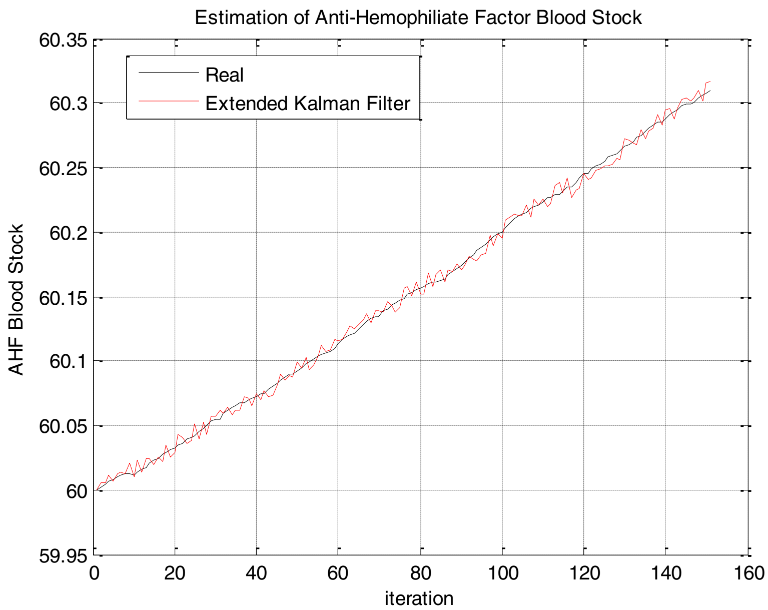

Figure 4. Estimation of AHF Blood Stock using EKF method with 150 iterations

Figure 4-6 is the Anti-Hemophiliate Factor (AHF) stock estimation results by the application of the EKF methods using 150, 250, and 350 iterations.Figures 4, 5 and 6 show that the estimation results of AHF blood stock had high accuracy with an error of less than 5%. as we can see in the real graphs. The accuracy of Extended Kalman Filter methods showed no significant difference.So it could be taken into consideration by PMI to get blood donors to avoid theoverload of blood stock of AHF type.

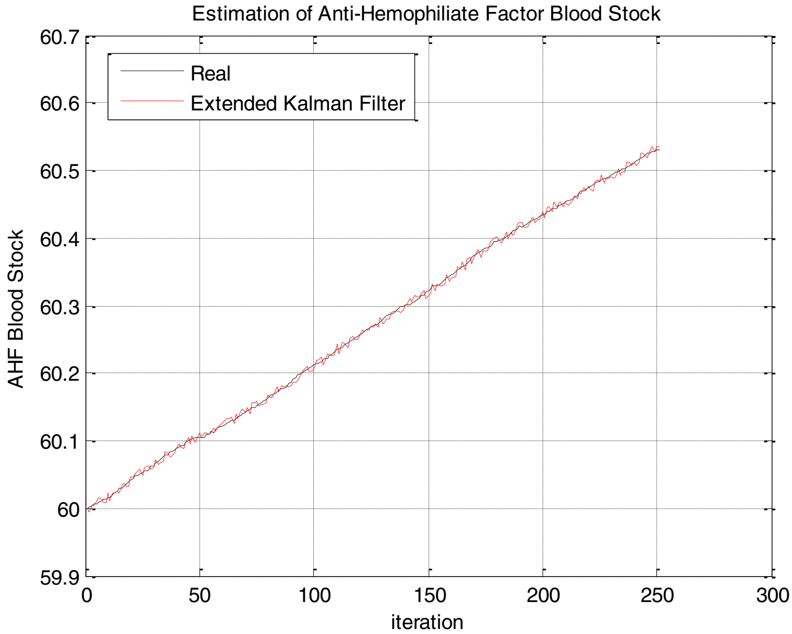

Figure 5. Estimation of AHF Blood Stock using EKF method with 250 iterations

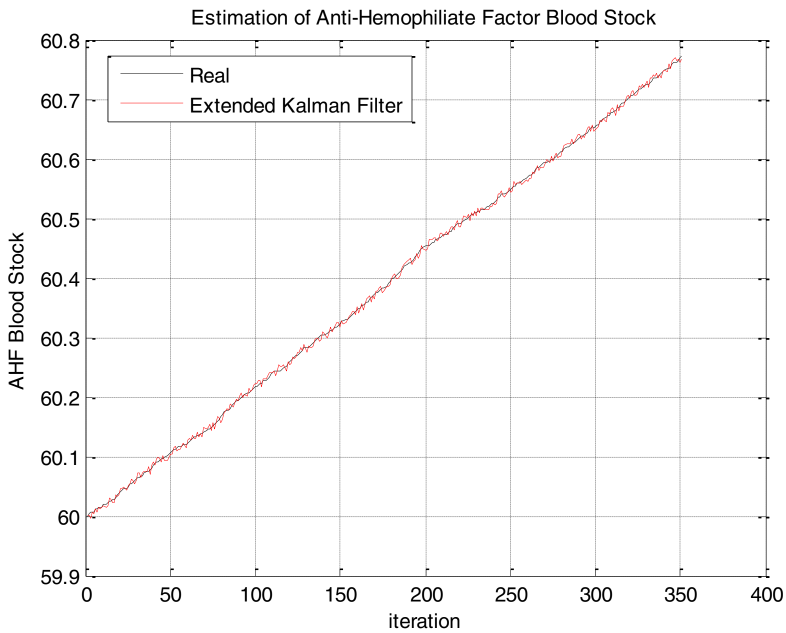

Figure 6. Estimation of AHF Blood Stock using EKF method with 350 iterations

In Table 3, it appears that the Extended Kalman Filter method using 350 iteration with RMSE of 0.00251 for WB Blood has higher accuracy than that of 250 and 150 iterations with RMSE of 0.00312 and 0.00381, and using 350 iterations with RMSE of 0.00451 for AHF blood has higher accuracy than that of 250 and 150 iterations with RMSE of 0.00484 and 0.00517. but the difference is not much. Likewise, in Figures 4 and 5 with 150 and 250 iteration. In conclusion, EKF method can be used as a method estimating either WB and AHF blood stock or other blood types.

Table 3. Comparison of theRMSE values by the EKF based on 150, 250 and 350 iteration

	150 Iteration		**250 Iteration**		**350 Iteration**	
	WB	**TC**	**WB**	**TC**	**WB**	**TC**
RMSE	0.00381	0.00517	0.00312	0.00484	0.00251	0.00451
Simulation Time	6,269 s		8,398s		10,462 s	

In general, the methods of Extended Kalman Filter can be used as a method to estimate Whole Blood (WB) and Anti-Hemophiliate Factor (AHF) blood stock with high accuracy. Based on the numeric simulation results above, it is likely that method can also be used to estimate other type of blood stock, so it can support the work of blood transfusion management.

5. Conclusion

Based Conclusion could be drawn based on the results of the simulation analysis that the EKF method is an effective method for estimating WB and AHF blood stock with excellent accuracy and an error of less than 5%. Thus, its application can support the work of blood bank management.

Open problem. How to implemented Fuzzy Kalman Filter (FKF) for estimation of other type of blood stock in all cities in Indonesia.

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