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Estimation of *Whole Blood* (WB) using Unscented Kalman Filter in Surabaya

Abdul Muhith[1*], Teguh Herlambang[1], Abdul Haris[2], Dinita Rahmalia[3]

[1]University of Nahdlatul Ulama Surabaya, Surabaya, Indonesia
[2]Universitas Panca Marga Probolinggo, Indonesia
[3]University of Islam Darul Ulum Lamongan

*abdulmuhith@unusa.ac.id

Abstract As the need for blood transfusion increases, an improved blood stock management for blood transfusion is required. In terms of quality and quantity, blood transfusion is needed by patients with various health problems. Because of that need, it is urgent that the stability of blood stock be maintained to avoid possible excessive blood stock that leads to unnecessary blood disposal. For that purpose, prediction of blood demand is required. One of the blood transfusion units is PMI, a national organization dealing with social concern and humanity field. The objective of this paper is to make estimation of blood demand for PRC and WB at PMI Surabaya using UKF method. The simulation results show that the UKF method is effective with a high accuracy and an error of less than 4%.

Keywords: *Whole Blood*, PMI Surabaya, estimation, UKF

1. Introduction

Blood is an important component in the body that carries nutrients and oxygen to all organs of the body, including vital organs such as the brain, heart, kidneys, lungs, and liver. If there is a lack of blood in the body caused by several things, the nutritional and oxygen requirements of these organs cannot be fulfilled. Tissue damage can occur quickly which leads to death. To prevent this, a blood supply from outside the body is needed. The process of transferring blood from a healthy person (donor) to a sick person / needy (recipient) is called a blood transfusion [1]. Blood transfusion has become an important part of health care. If blood transfusions are applied correctly, transfusion can save the lives of patients and can improve the health status of these patients.

Estimation of the number of requests is required in the health field. Blood is very important in human life. Blood is a liquid in the body, needed to transport oxygen needed by cells throughout the body [2]. To minimize errors, it is necessay to estimate the number of blood requests at the Indonesian Red Cross (PMI) [3]. Estimates are made because a problem can sometimes be solved using presvious information or data related to the problem [4,5,6]. One estimation method is the Extended Kalman Filter (EKF) which functions to minimize covariance error estimation in correction step [7]. In this paper, the estimation of the demand for WB blood is limited only to PMI Surabaya City. The development of the Kalman Filter method is the Unscented Kalman Filter (UKF) obtained by applying sigma point at the prediction stage. In this paper, UKF method was applied to estimate the demand for WB blood as the basis of the consideration of the blood management at PMI Surabaya City.

2. Methodology

2.1 Blood Data of Whole Blood (WB)

The data of Whole Blood (WB) 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												

2.2 Unscented Kalman Filter

Algorithm of Unscented Kalman Filter is writen as follows [7]:

- *Initiation at k = 0*:

$$\hat{x}_0 = E[x_0]$$
$$\mathrm{P_{x_0}} = \mathrm{E}[(\mathrm{x}_0 - \hat{\mathrm{x}}_0)(\mathrm{x}_0 - \hat{\mathrm{x}}_0)^{\mathrm{T}}]$$
$$\hat{x}_0^a = E[x^a] = E\left[\hat{x}_0{}^T \;\; 0 \;\; 0\right]^T$$
$$P_0^a = E[(x_0^a - \hat{x}_0)(x_0^a - \hat{x}_0)^T] = \begin{bmatrix} P_x & 0 & 0 \\ 0 & P_v & 0 \\ 0 & 0 & P_n \end{bmatrix} \quad (1)$$

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:

$$\gamma = \sqrt{L+\lambda}$$
$$\lambda = \alpha^2(L + \kappa) - L \quad (2)$$

2) Time-update (prediction stage)

$$X_{k|k-1}^x = f(X_{k-1}^x, X_{k-1}^v)$$
$$\hat{x}_k^- = \sum_{i=0}^{2L} W_i^{(m)} X_{i,k|k-1}^x$$
$$P_{x_k}^- = \sum_{i=0}^{2L} W_i^{(c)}\left(X_{i,k|k-1}^x - \hat{x}_k^-\right)\left(X_{i,k|k-1}^x - \hat{x}_k^-\right)^T$$
$$Z_{k|k-1} = H(X_{k|k-1}^x, X_{k-1}^n)$$
$$\hat{z}_k^- = \textstyle\sum_{i=0}^{2L} W_i^{(m)} Z_{i,k|k-1} \quad (3)$$

3) Measurement update (cortrection stage):

$$P_{\bar{z}_k,\bar{z}_k} = \sum_{i=0}^{2L} W_i^{(c)}\left(Z_{i,k|k-1} - \hat{z}_k^-\right)\left(Z_{i,k|k-1} - \hat{z}_k^-\right)^T$$
$$P_{x_k,z_k} = \sum_{i=0}^{2L} W_i^{(c)}\left(X_{i,k|k-1}^x - \hat{x}_k^-\right)\left(Z_{i,k|k-1} - \hat{z}_k^-\right)^T$$
$$K_k = P_{x_k,z_k} P_{\bar{z}_k,\bar{z}_k}^{-1}$$
$$\hat{x}_k = \hat{x}_k^- + K_k(z_k - \hat{z}_k^-)$$
$$P_{x_k} = P_{x_k}^- - K_k P_{\bar{z}_k} \mathrm{K}_k^T \quad (4)$$

3. Discussion and Analysis

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

$$f(x) = 1025.13 - 1.3789x - 0.371\, x^2$$
$$f'(x) = -1.3789 - 0.742\, x \tag{5}$$

from equations (2), the modified WB blood stock function model in (5) is discreted using the finite difference method and obtained as follows:

$$f_{k+1} = (-1.3789 - 0.742\ x_k)\Delta$$

After the function was got, then it was computation simulated with the Matlab software. In this paper a simulation was applied by applying the Unscented Kalman Filter (UKF) algorithm to the function of blood stock of WB type. The simulation results were evaluated by comparing the real conditions in the field with the estimation results of UKF. This simulation used $\Delta t = 0{,}1$ and 100, 200, and 300 iteration. Figure 1 is the estimation results using UKF methods using 100 iteration. Figure 2 is the simulation result of the UKF methods using 200 iteration. Figure 3 is a simulation of the UKF methods by 300 iteration.

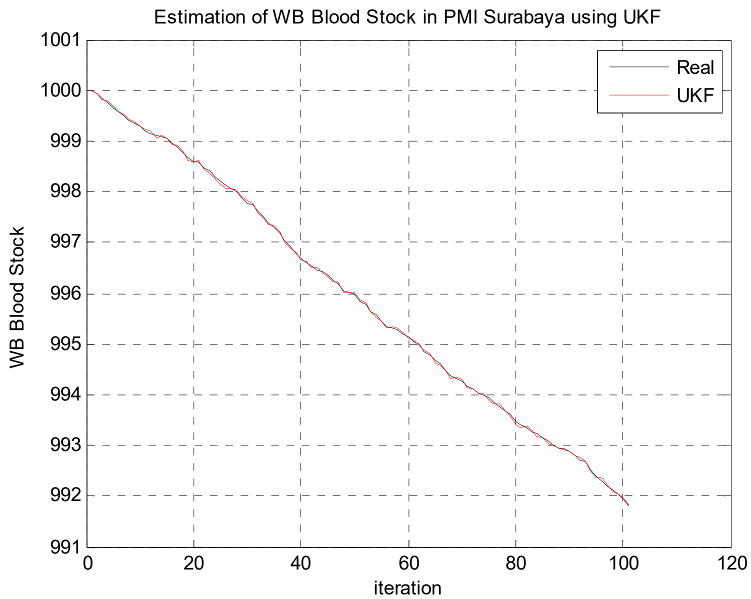

Figure 1. Estimation of WB blood using UKF methods with 100 iteration

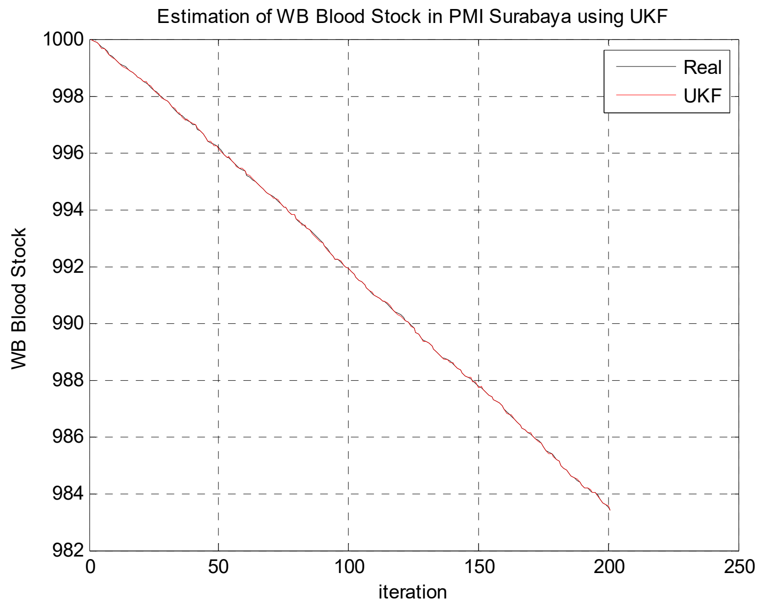

Figure 2. Estimation of WB blood using UKF methods with 200 iteration

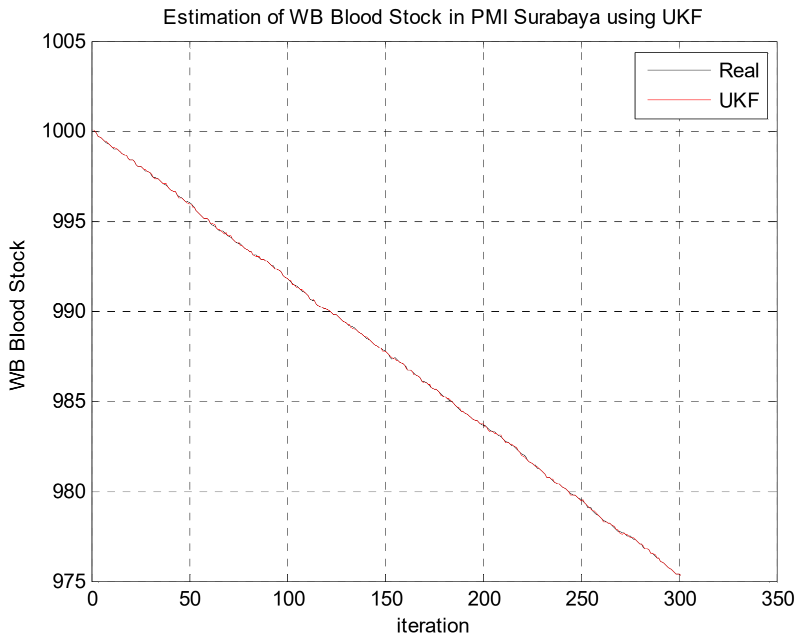

Figure 3. Estimation of WB blood using UKF methods with 300 iteration

Figures 1, 2 and 3 show that the estimation results of WB blood stock have high accuracy with errors of less than 4% as we can see in the real graphs. The accuracy of Unscented Kalman Filter methods showed no significant difference. In Figure 1 and Table 2, it appears that the Unscented Kalman Filter method using 300 iteration with RMSE of 0.00321has higher accuracy than that of 200 and 100 iteration with RMSE of 0.00407and 0.00491, but the difference is not much. Likewise, in Figures 2 and 3 with 200 and 300 iteration. In conclusion, UKF method can be used as a method estimating either WB blood stock or other blood types.

Table 2. Comparison of the RMSE values by the UKF based on 100, 200 and 300 iteration

	100 Iteration		**200 Iteration**		**300 Iteration**	
	RMSE	**Accuracy**	**RMSE**	**Accuracy**	**RMSE**	**Accuracy**
RMSE	0.00491	96,2%	0.00407	97%	0.00321	97,5%
Simulation Time	6,189 s		8,256 s		10,371 s	

In general, the methods of Unscented Kalman Filter can be used as a method to estimate Whole Blood (WB) 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 PMI Surabaya's blood transfusion management in blood bank

4 Conclusion

Based on the results of the simulation analysis and discussion, Unscented Kalman Filter (UKF) method can be used as a method to estimate WB blood stock with excellent accuracy and errors of less than 4%. Based on the simulation results above, it is likely that both methods can also be used to estimate othertype of blood stock, so it can support the work of PMI Surabaya's blood bank management in particular and PMI in all cities in Indonesia in general.

References

[1] Weinstein, R. 2012 Clinical Practice Guide on Red Blood Cell Transfusion. American Society of Hematology

[2] Ohsaka, A., Abe, K., Ohsawa, T., Miyake, N., Sugita, S., & Tojima, I. (2008). A komputer-assisted transfusion management sistem and changed transfusion practices contribute to appropriate management of blood components. *Transfusion, 48*(8), 1730-1738.

[3] Shanty, W., Firdaus., Herlambang, T., 2018. “Prediction of Availability of Packed Red Cells (PRC) at PMI Surabaya City Using Ensemble Kalman Filter as Management of Blood Transfusion Management”, The Second Internatonal Conference on Combinatorics, Graph Teory and Network Topology, University of Jember-Indonesia, 24-25 Nov 2018, Journal of Physics: Conf. Series 1211 (2019) 012031

[4] Herlambang, T., 2017, “Design of a Navigation and Guidance System of Missile with Trajectory Estimation Using Ensemble Kalman Filter Square Root (EnKF-SR). International Conference on Computer Applications and Information Processing Technology (CAIPT)-IEEE, Bali Indonesia 8-10 Augsut 2017

[5] Karya, D.F., Puspandam, K. and Herlambang, T., 2017. “Stock Price Estimation Using Ensemble Kalman Filter Square Root Methods”, The First Internatonal Conference on Combinatorics, Graph Teory and Network Topology, University of Jember-Indonesia, 25-26 Nov 2017, Journal of Physics: Conf. Series 1008 (2018) 012026.

[6] Puspandam, K., Fidita, D.F., Herlambang, T.,and Khusnah,H., 2018. “Ensemble Kalman Filter for Crude Oil Price Estimation,”, The Second Internatonal Conference on Combinatorics, Graph Teory and Network Topology, University of Jember-Indonesia, 24-25 Nov 2018, Journal of Physics: Conf. Series 1211 (2019) 012031

[7] Karya, D.F., Puspandam, K., Herlambang, T., and Rahmalia D., 2018. “Development of Unscented Kalman Filter Algorithm for stock price estimation”, The Second Internatonal Conference on Combinatorics, Graph Teory and Network Topology, University of Jember-Indonesia, 24-25 Nov 2018, Journal of Physics: Conf. Series 1211 (2019) 012031.