



Cristian P. Chioncel, Petru Chioncel

Implementation of the Kalman Filter Algorithm on a Stand With Microcontroller

The experimental stand represents an application to adjust and control the rotation speed of a DC motor with permanent magnet realized with an 80C51 family microcontroller that commands a PWM (Pulse Wide Modulation) source. The user interface is realized in Visual Basic 6. It contains different adjustment modes and posts the state estimation of the process (rotor speed and current of the DC motor). It can be observed good conformity between the estimate values (calculated), and the measured once.

1. Introduction

The modern driving processes have known a great development once with the appearance of the microcontroller technology that created the theoretical and practice base to concept and realize digital control systems. This command and control systems are based on different estimation methods connected with a control scheme, the estimation eliminates the a priori unknown of the parameters and/or states. The objective of the present paper consists exactly in the presentation of an on-line state estimation algorithm, the so called Kalman filter algorithm, implemented on a stand with microcontroller. The estimation algorithm works in real time if he is recursive and has the property to follow slowly variation of the states.

2. The Kalman filter implementation on an stand with microcontroller for the speed control of an DC motor

The block scheme of the microcontroller stand on that the Kalman filter algorithm was implemented is shown in figure 1 and contains: μC – microcontroller where the numerical process control was implemented through a numerical algorithm control. The controller and the comparison element C that determinates the deviation that constitutes the input size in to the controlled system. The output

of the control block generates the command size, based on the chosen control algorithm (P – proportional, or PI proportional - integrative). The stand execution element is made up from a stabilized voltage source (PWM Pulse Wide Modulation) that supplies the DC motor with permanent magnet, that represents the technical lead process. The feedback translation was made for this stand from an sinusoidal signal generator with permanent magnets that assures, through a simple pulse counting, the numerical translation of the motor speed. The execution element, PWM, together with the feedback translate element implements in the same time the function of analog numeric and numeric analog conversion, simplifying on this way the classical structure of the digital control system.

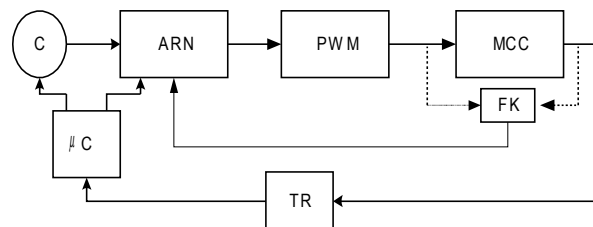


Figure 1 Stand block scheme

The Kalman filter algorithm estimates the basic state element of the controlled process, for this case the motor speed and the rotor current of DC motor with permanent magnet. The Kalman algorithm, presented as follows, has been implemented as a program written in Visual Basic 6.0.

Table 1 Steps of the recursive Kalman filter algorithm

| Predict (time update) | Correct (measurement update) |
|---|---|
| (1) Project the state ahead $\hat{x}_{k+1} = \phi_k \hat{x}_k$ (2) Project the error covariance ahead $P_{k+1}^- = \phi_k P_k \phi_k^T + Q_k$ | (1) Compute the Kalman gain $K_k = P_k^- H_k^T (H_k P_k^- H_k^T + R_k)^{-1}$ (2) Update estimate with measurement z_k $\hat{x}_k = \hat{x}_{k+} + K_k (z_k - H_k \hat{x}_{k+})$ (3) Update the covariance error $P_k = (I - K_k H_k) P_{k+}^-$ |

Table 1 offers a complete picture of the Kalman filter operation that processes discrete measurements (input) into optimal estimates (the output), where z_k – vector measurement at time t_k , H_k – matrix given the ideal connection between the

measurement and the state vector at time t_k , v_k – measurement error, Q_k , R_k - covariance matrices for the vectors v_k and w_k , \hat{x}_k^- - aprior estimate, \hat{x}_k - the update estimate, K_k an blending factor or Kalman gain, P_k - error covariance matrix, P_{k+1}^- - error covariance matrix associated with the updated estimated.

The PC is connected trough the serial port (COM 1) to the stand. To control the implemented function, the user has at his disposition a graphical interface, presented in figure 2. This contains the input sizes and their change trough virtual buttons, accessed from the user by the mouse, as follows: START – the start and stop button that connects and disconnects the motor, REGULATOR (controller) - when this button is accessed the system works in automatic controlled mode, holding the motor speed on a constant value, UP – increase the PWM value (command voltage) with 1% one percent; DOWN – decreases the PWM value (command voltage) with one percent; PWM – displays the PWM voltage value in percent (initial value - 75 %); RPM – displays the motor rotor speed multiplied with the factor 10; P, PI – buttons that activates the control mode: P – proportional or PI – proportional integrative; sample time control scroll (0.1 – 1s); Kalman – button that activates the Kalman estimation for current and motor speed.

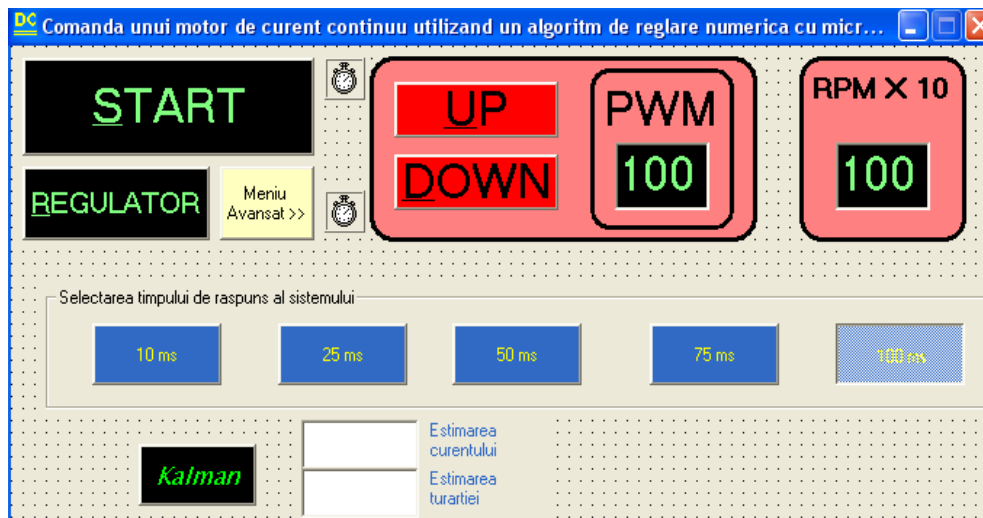


Figure 2 User interface

3. Results of the state estimation

The mathematic model of the DC motor drive have been used to build up the matrix A, B, C and D for the state space process model and for the Kalman algorithm matrixes.

The state space representation of the DC motor driving an inertial load as a dynamical system is given by the equation (1) and (2):

$$\frac{d}{dt} \begin{bmatrix} i \\ \omega \end{bmatrix} = \begin{bmatrix} -\frac{R}{L} & -\frac{K_b}{L} \\ \frac{K_m}{J} & -\frac{K_f}{J} \end{bmatrix} \cdot \begin{bmatrix} i \\ \omega \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} \cdot u_{ap}(t) \quad (1)$$

$$y(t) = \begin{bmatrix} 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} i \\ \omega \end{bmatrix} + \begin{bmatrix} 0 \end{bmatrix} \cdot u_{ap}(t) \quad (2)$$

where I – current, ω - angular rate, R – circuit resistance, L – self inductance of the armature, K_m – armature constant, u_{ap} – applied voltage.

Improving the performances of the control systems depends in a decisive measure from the quality estimation of the process parameters. Figure 3 presents the estimation results obtained with the process functioning in open circuit.

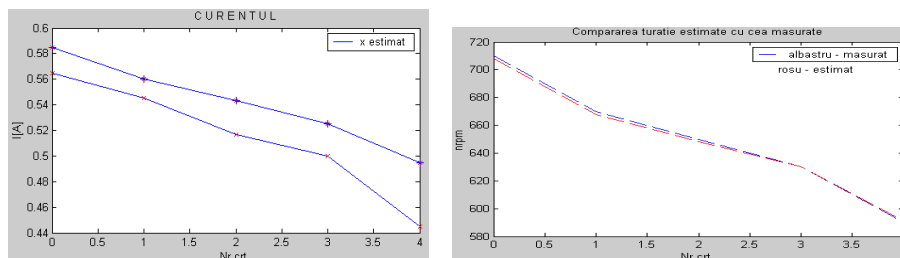


Figure 3 Current and motor speed estimation

4. Conclusion

The results of the Kalman estimated parameters converge after a reduced number of iteration to the real value, once with the Kalman gain is fixed.

References

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- Prof. Dr.Eng. Petru Chioncel, " Eftimie Murgu" University of Resita, Piața "Traian Vuia", nr. 1-4, Reșița, p.chioncel@uem.ro
- Asist.Eng. Cristian P. Chioncel, " Eftimie Murgu" University of Resita, Piața "Traian Vuia", nr. 1-4, Reșița, c.chioncel@uem.ro