System Theory
project: Model Predictive Control Using FPGA

Due on Thursday, June 21, 2018

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1 Introduction

This journal paper (**Model Predictive Control Using FPGA**) is trying to use MPC for motor speed control. In addition, they also deploy their method into FPGA. So they will varify their algorithm and model parameters by MATLAB and then convert the code to C program. Afterwards, they will use the SDK provided by FPGA manufacturer to export program into FPGA board.
In this report, I will implement the MPC algorithm to simulate the system provided by this paper.

1.1 Model Predictive Control

Give a state-space model as

$$x(k+1) = A_m x(k) + B_m u(k) \tag{1}$$
$$y(k) = C_m x(k) \tag{2}$$

then we can further create augmeted model

$$x(k+1) = Ax(k) + Bu(k) \tag{3}$$
$$y(k) = Cx(k) \tag{4}$$

For each time of iteration, we will use Quadratic Programming to solve an non-linear system

$$\min_{\Delta U} \frac{1}{2}\Delta U^T H \Delta U + \Delta U^T f \tag{5}$$
$$A\Delta U \leq b \tag{6}$$

In **Receding Horizon Control**, we will only use the first element of ΔU and re-compute the QP for next iteration.

2 Simulation Result

2.1 System Model

In this paper, the state-space model is

$$A_m = \begin{bmatrix} -0.0001 & 0 \\ 3.3864 & 0.9974 \end{bmatrix} \tag{7}$$
$$B_m = \begin{bmatrix} 0.0025 \\ 0.2594 \end{bmatrix} \tag{8}$$
$$C_m = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \tag{9}$$
$$N_c = 3 \tag{10}$$
$$N_p = 10 \tag{11}$$

However, in this paper they say the weight matrix Q and R need to be finetune but they didn't give me the exact value. So the matrix H is unknown and I directly use the matrix provided in class book with

$$H = \Phi^T \Phi + \bar{R} \tag{12}$$
$$f = -2\Phi^T (R_s - Fx(k_i)) \tag{13}$$

2.2 Result

Fig. 1 and 2 is the predicted control sigal from the paper and my implementation, respectively.

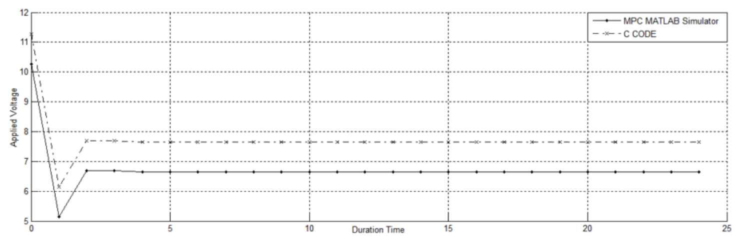

Figure 1: The predicted control value (solid line) u in the paper.

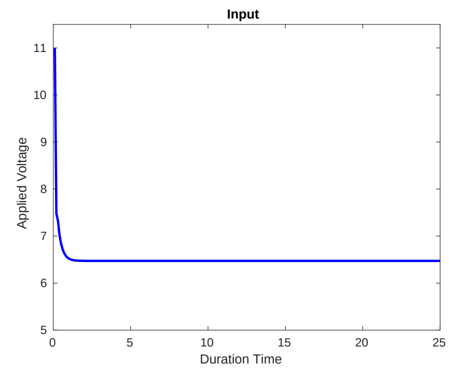

Figure 2: The predicted control value u with my implementation.

Fig. 3 and 4 is the output sigal from the paper and my implementation, respectively.

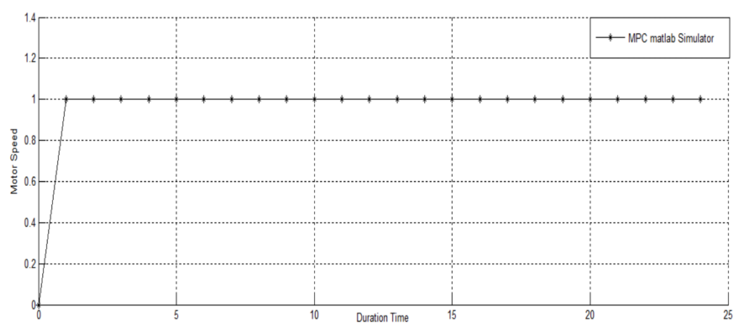

Figure 3: The output signal y in the paper.

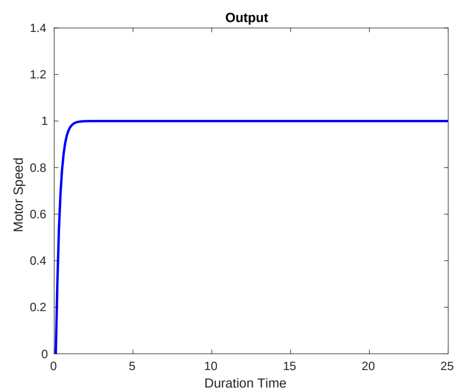

Figure 4: The output signal y with my implementation.

For the output signal, my result is almost same as the result of paper. For the predicted control signal, the predicted control value from this paper has a small over shoot, which doesn't appear in my implementation. I think the reason is because the QP parameters H and f is different from the ones they use in this paper, so I cannot perfectly reproduce the result. However, the overall convergence is same, so I think my implementation is correct.