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INFLUENCE OF CONTROL HORIZON TO CONTROL QUALITY IN PREDICTIVE CONTROL

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Abstract: *This paper deals predictive control and influence control horizon to quality of control. The paper has two parts. The first part of this paper deals with the design of algoritms for predictive control for discrete second order model. The next part performed simulations for different control horizons and evaluation of quality control.*
Key words: *predictive control, simulation, control quality, maximum horizont, Matlab Simulink*

1. INTRODUCTION

Predictive control is one of the methods of control design, which has obtained very popular in recent years. Predictive control is based on the use of processes discrete models, and therefore the derivation of the algorithm is implemented mainly in discrete area.

2. PREDICTIVE CONTROL

The term Model Predictive Control presents a class of control methods which have common particular attributes (Camacho & Bordons, 2004; Mikleš & Fikar, 2007; Bobál et al., 2009; Bobál, 2009):

- Mathematical model of a systems control is used for prediction of future control of a system output.
- The input reference trajectory in the future is known.
- A computation of the future control sequence includes minimization of an appropriate objective function (usually quadratic one) with the future trajectories of control increments and control errors.
- Only the first element of the control sequence is applied and the whole procedure of the objective function minimization is repeated in the next sampling period.

The principle of Model Based Predictive Control (MBPC) is shown in Fig. 1, where $u(t)$ is the manipulated variable, $y(t)$ is the process output and $w(t)$ is the reference signal, N_1, N_2 and N_u are called minimum, maximum and control horizon. This principle is possible to define as follows:

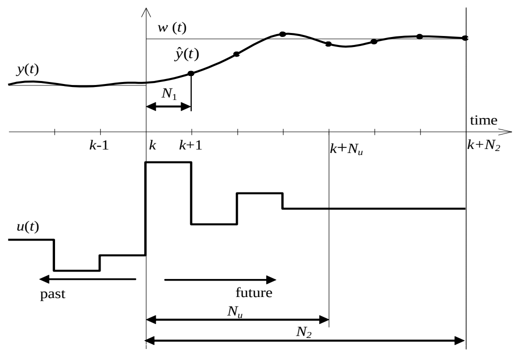

Fig. 1. Principle of MBPC

1. The process model is used to prediction of future outputs $\hat{y}(t)$ over maximum horizon N_2. The predictions are calculated based on information up to time k and on the future control actions that are to be determined.
2. The future control trajectory is calculated as a solution of an optimisation problem consisting of objective function and possibility some constraints. The cost function comprises future output predictions, future reference trajectory, and future actions.
3. Although the whole future control trajectory was calculated in the previous step, only first element $u(k)$ is actually applied to the process. At the next sampling time, the procedure is repeated. This is known as the *Receding Horizon* concept.

In this paper the Generalized Prediction Method (GPC) will be used (Clarke et al., 1987).

3. ALGORITHM DERIVATION

Discrete transfer function of second order system has the form:

$$G_S(z^{-1}) = \frac{Y(z^{-1})}{U(z^{-1})} = \frac{b_1 z^{-1} + b_2 z^{-2}}{1 + a_1 z^{-1} + a_2 z^{-2}} = \frac{B(z^{-1})}{A(z^{-1})} \tag{1}$$

CARIMA model has the form:

$$\Delta A(z^{-1}) y(k) = B(z^{-1}) u(k) + C(z^{-1}) e_s(k) \tag{2}$$

where $u(k)$ and $y(k)$ are control and output sequence control system, $e_s(k)$ is white noise. A, B and C are polynomials.
When polynomial $C(z^{-1}) = 1$ and $e_s(k) = 0$ then equation (2) describes deterministic system. Substituting individual polynomials from equation (1) to equation (2), the CARIMA model has the following form:

$$\begin{aligned} y(k) = {} & (1 - a_1) y(k-1) + (a_1 - a_2) y(k-2) + \\ & + a_2 y(k-3) + b_1 \Delta u(k-1) + b_2 \Delta u(k-2) \end{aligned} \tag{3}$$

For a general calculation of predictive control for second-order system, must be calculated the first three equations of predicted output.

$$\begin{aligned} \hat{y}(k+1) = {} & (1 - a_1) y(k) + (a_1 - a_2) y(k-1) + \\ & + a_2 y(k-2) + b_1 \Delta u(k) + b_2 \Delta u(k-1) \end{aligned} \tag{4}$$

$$\begin{aligned} \hat{y}(k+2) = {} & (1 - a_1) \hat{y}(k+1) + (a_1 - a_2) y(k) + \\ & + a_2 y(k-1) + b_1 \Delta u(k+1) + b_2 \Delta u(k) \end{aligned} \tag{5}$$

$$\begin{aligned} \hat{y}(k+3) = {} & (1 - a_1) \hat{y}(k+2) + (a_1 - a_2) y(k+1) + \\ & + a_2 y(k) + b_1 \Delta u(k+2) + b_2 \Delta u(k+1) \end{aligned} \tag{6}$$

Iteratively substituting equations (3) to (4), and (3), (4) to (5), and (3), (4), (5) to (6) were obtained resulting equations of predicted output through which can be compiled matrix of free and forced system responses.

4. SIMULATION

For simulation was used software The MathWorks™ Matlab and Matlab Simulink®.
In the first step was created initialization script, where was set parameters of system a_1, a_2, b_1, b_2 and sample time T_0. Further was set individual horizons N_1, N_2, N_u, penalty constant λ and reference value. Output of the initialization script is calculate matrix of free and forces responses and controller parameters to calculate control value.
In second step was created simulation scheme with Matlab Simulink®.

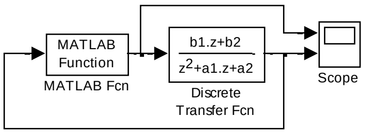

Fig. 2. Simulink scheme to control

In Fig. 2. is shown Simulink scheme, which was used to simulation. To scheme contains only three blocks. Block *"MATLAB Fcn"* is used as predictive control, which executes second script (function) for calculate control value in sample time. Block *"Discrete Transfer Fcn"* is used as controlled system. The last block *"Scope"* is used to graphic display of control.
The discrete transfer function of system was given in form:

$$G_S(z^{-1}) = \frac{0.05075z^{-1} + 0.0421z^{-2}}{1 - 1.478z^{-1} + 0.5712z^{-2}} \qquad T_0 = 0.35\ s \qquad (7)$$

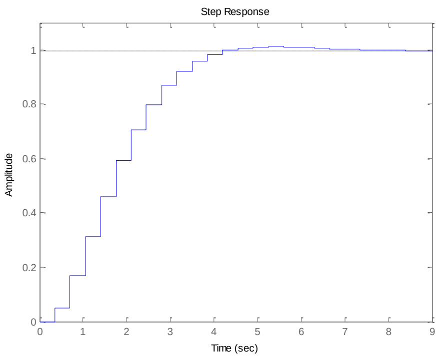

Fig. 3. Step response of control system

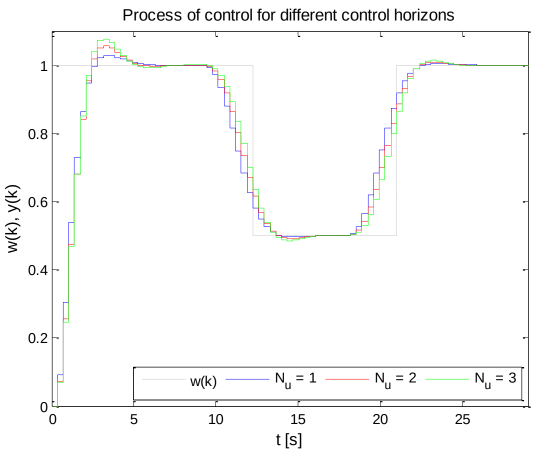

Fig. 4. Process of control for different control horizons

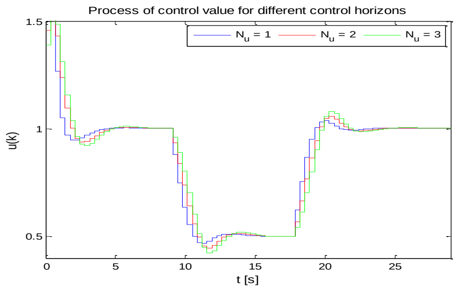

Fig. 5. Process of control value for different control horizons

Minimal and maximal horizon of predictive control were determined from step response (see Fig. 3.) $N_1 = 1$ and $N_2 = 8$. The control horizon N_u was set from 1 to 3. The penalty constant was set $\lambda = 1$. Reference value was selected in the form of steps.

N_u	S_y	S_u
1	0.0372	0.0051
2	0.0373	0.0028
3	0.0366	0.0028

Tab. 1. Control quality

Parameters of control quality S_y and S_u were calculated subsequently:

$$S_y = \frac{1}{k_2 - k_1 + 1} \sum_{i=k_1}^{k_2} e(i)^2 \qquad (8)$$

$$S_u = \frac{1}{k_2 - k_1 + 1} \sum_{i=k_1}^{k_2} \Delta u(i)^2 \qquad (9)$$

The choise of control horizon in case of predictive control had main effect to course of control value and control speed. Especially ther overshoot output value has been influenced. If control horizon value was increased, the control value overshoot was also greater.

5. ACKNOWLEDGEMENTS

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