Model predictive control approach for the system of multi input single output

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Abstract. This study aims to determine the control optimization system with Model Predictive Control (MPC) for the plant of Multi Input Single Output (MISO). The MPC optimal control system designed for the closed-loop Mismatch method, and the effect of changes in the Kalman amplifier state estimator. The study conducted with simulation work using Simulink in MATLAB. The results of these experiments show that the output by changing the Kalman amplifier produces a more structured graph compared to MPC Controller.

1. Introduction

The development of technology today cannot be denied, especially in the era of the industrial revolution 4.0. All parties have flocked to take advantage of technology in carrying out their day-to-day activities and keep abreast of technological developments so as not to be left behind. Technological developments also affect the sustainability of human activities. Along with these developments, humans are faced with what is called automation [1].

Reflecting on this, the control in a system becomes a calculation. This is very much felt in the industrial world. Companies have changed their operating systems to be automatic in order to keep up with the era of development [2]. This is also the criterion for the 4.0 industrial revolution. Companies have implemented this for example controls in the stir tank, conveyor, tank level and others. System control is also felt in people's daily lives, for example with the advent of smart homes, which include smart lighting, smart and safe doors, automatic air conditioning and others [3] [4].

The function of the control system is for maintaining a plant stability in accordance with target objectives, minimize errors, and improve system performance [5] [6]. The control system works in order to achieve the goal, namely reaching the target with an error value in conditions that are always close to zero. The output of a plant is a constant value, therefore a control system is needed so that the output value can reach the target with a minimum error value.
A modelling with a good predictive rate is necessary to create a good performance of the predictive controller [7]. The right model to use is the Predictive Control (MPC) Model or Predicted Control Model. MPC is a sophisticated process control method used to control a process while meeting a series of constraints. This model is an effective way of dealing with large multivariable controlled control problems [8, 9]. In this article, we will discuss MPC on Multi Input Single Output (MISO).

The MPC model is a control system that uses predictive results to issue input controls [10]. The basic concept of MPC is the utilization of long-term prediction of process output to make minimum target for one or more of the function criterion to obtain an optimal control law [11]. There are various MPC design methodologies depending on the dynamic model of the process, process or measurement noise, and the cost function which should be minimized [12].

MPC uses the same cost function as LQR, namely the quadratic cost function [13, 14]. Based on this cost function, MPC produces optimal input control for some time to come (prediction result), but only current input control is applied to the plant. The next time, the calculation based on the cost function is repeated and only the current input controls are applied, and so on. One of the advantages of MPC is that this technique takes into account the constraints of input and output values [15].

2. Model predictive control method

The MPC work diagram can be seen in Figure 1.

Figure 1. Diagram of MPC

MPC Variable Work Diagram in MPC is divided into three, namely disturbance variables (DV), controlled variables (CV), and manipulated variables (MV). MV was changed to keep CV within limits. This is achieved in the presence of DV which interferes with the process. The system model used for MPC is an empirical model obtained from step tests in the system or dynamic models. This empirical model was developed from step test data and model identification. In the every step, MPC can give the solves of optimization problem to obtain the best steady state for operating the plant. This technique is usually formulated as a linear or quadratic program.

Over the past few years, there has been much solid theoretical basis for MPC so that large-scale Multi Input Single Output (MISO) controllers with guaranteed non-conservative stability can be routinely designed. MISO is an antenna technology for wireless communication where multiple antennas are used at the source. Antennas are combined to minimize errors and optimize data. In this study, the MPC control system simulation on MISO has been carried out. The MPC simulation on MISO is done using Simulink in the MATLAB software.
3. Findings and discussion

This control system is designed with an MPC which has one measured output and 3 inputs, namely one manipulated variable (MV), one measured disturbance (MD), and one unmeasured disturbance (UD). The system circuit is a closed loop and simulated via Simulink. Optimal Control System with MPC approach for a plant of MISO. In this study, the system used has inputs and output of 3 and 1 respectively. The state space of the system in this study can be written with equation (1)

\[
\text{sys} = \text{ss}(\text{tf}([1,1,1,1.2],[1.4,1.2],[1,1.2],[0.8,0.6,1.2])))
\] (1)

with the following explanation:

System arises from input 1 to output can be written with the equation (2).

\[
G(s) = \frac{1}{s^2+0.4s+1.2}
\] (2)

While the system arises from input 2 to output can be presented with the equation (3).

\[
G(s) = \frac{1}{s+1.2}
\] (3)

Whereas the system from input 3 to output can be structured with the equation (4).

\[
G(s) = \frac{1}{0.8s^2+0.6s+1.2}
\] (4)

Subsequently using the function of statespace (ss) in matlab software, the transfer function of 1x3 can be transformed to the model of state space. Through the script of sys = ss(sys) on the matlab command window, it can be obtained the following matrices of A, B, C and D.

\[
A = \begin{bmatrix}
-0.4 & -1.2 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 \\
0 & 0 & -1.2 & 0 & 0 \\
0 & 0 & 0 & -0.75 & -1.5 \\
0 & 0 & 0 & 1 & 0 \\
\end{bmatrix}
\]

\[
B = \begin{bmatrix}
1 \\
0 \\
0 \\
0 \\
0 \\
\end{bmatrix}
\]

\[
C = \begin{bmatrix}
0 & 1 & 1.1 & 0 & 1.5 \\
\end{bmatrix}
\]

\[
D = \begin{bmatrix}
0 & 0 & 0 \\
\end{bmatrix}
\]
Optimal Control System with MPC using Mismatch approach for the closed-loop plant. In this study, through a robustness testing was carried out on the MPC controller with mismatch approach on the plant model. While the program was be operated, it will obtain the performances for input and output that can be seen at Figure 2 and Figure 3 respectively.

Figure 2. The input performances

Figure 3. The output performances
Kalman gain for the state estimator. The Kalman amplifier is used to estimate conditions, disturbances, and noise that occur in a model being worked on. This refers to pre-existing data. In this study, by changing the Kalman amplifier, it is found that the prediction from the output graph will be like Figure 4.

![Figure 4. Comparison between input and optimal output](image)

The comparisons that can be seen from these controls through using the Kalman filter, the state variable estimation becomes more structured and optimal. This output performances can be seen in Figure 3 and Figure 4.

4. Conclusion
This study demonstrates the application of MPC control system optimization system with multiple inputs and single output. This system simulates using the Simulink of MATLAB. The MPC control can predict the results of a process being carried out. This is very helpful in order to reduce errors as minimum as possible during a process. With the Kalman filter, results can be predicted in a more structured manner.

References
[1] Liping F, Zhang J, Huang X, Huang D. 2012. The design of the MISO Model Predictive Controller for Bioreactor. TELKOMNIKA.10(6), 1163-1170
[2] Nur H, Fatchul A, Dessy I, Muslikhin, Zainal A. (2017). Teaching Aid For Diagnosing Motorcycle Damages Using Back Propagation Artificial Neural Network. Jurnal Pendidikan Teknologi dan Kejuruan (JPTK), 26(2).
[3] Ali D, Jalel G, Hassani M. 2007. Robust Predictive Control using a GOBF Model for MISO Systems. International Journal of Computers, Communications & Control. II(4): 355-366.
[4] Khadir and Ringwood. 2003. Linear and nonlinear model predictive control design for a milk pasteurization plant. Control and Intelligent Systems. 31(1): 1-8.

[5] Senthil KA, Zainal A. 2012. Model Predictive Control (MPC) and Its Current Issues in Chemical Engineering. Chemical Engineering Communications 199(4):472-511

[6] Serela G, Fiorentini M, Capozzoli A, Bernardini D. 2018. Model Predictive Control (MPC) for Enhancing Building and HVAC System Energy Efficiency: Problem Formulation, Applications and Opportunities. Energy. 11(631): 1-35.

[7] Khairudin M, Mohamed Z, Husain AR. 2011. Dynamic model and robust control of flexible link robot manipulator. Telkomnika 9 (2). pp.279.

[8] Rawlings JB, Mayne DQ, Diehl MM. 2019. Model Predictive Control: Theory, Computation, and Design. Nob Hill Publishing. LLC.

[9] Nwobi CC., Stanley O, Anthony CI. 2016. Performance evaluation of Multi Input Single Output (MISO) production process using transfer function and fuzzy logic: case study of a brewery. Ain Shams Engineering Journal. 7 (3) : 1001-1010.

[10] Khairudin, M., Wijaya, H.A., Muslihin. 2020. Converter matlab fuzzy inference to arduino System. Journal of Physics: Conference Series 1456 (1)

[11] Azagra JR, Martinex MG, Elso J. 2014. Quantitative Feedback Control of Multiple Input Single Output Systems. Mathematical Problems in Engineering. 2014.

[12] Shun Y, Smith R, Hwang S. 2020. Development of model predictive control system using an artificial neural network: A case study with a distillation column. Journal of Cleaner Production. 277.

[13] Gango D, T. P’eni, R. Toth. 2019. Learning based approximate Model Predictive Control for nonlinear system. IFAC PapersOnLine. 52 (28) : 152-157.

[14] Nelson JR, Johnson NG. 2020. Model predictive control of microgrids for real-time ancillary service market participation. Applied Energy. 269.

[15] Dou T, Lopes YK, Rockett P. 2020. Model predictive control of non-domestic heating using genetic programming dynamic models. Applied Soft Computing.