УДК 681.5

ADAPTIVE COMPENSATION BASED ON PARAMETERIZING DISTURBANCES OF 2-DOF ROBOTIC MANIPULATOR WHEN MEASURING ONLY THE OUTPUT

Hoang D.L. (ITMO University)
Scientific supervisor – associate professor, docent, Dudarenko N.A. (ITMO University)

Abstract. In this paper, an adaptive compensation of unknown external disturbances for a 2-DOF robotic manipulator when measuring only the outputs is presented. A 2-DOF robotic manipulator is affected by unknown external disturbances, which are defined by the parameterizing method. After that, the measured disturbance model is transferred into the filter model that is used to design the adaptive compensation. The adaptive compensation algorithm is based on the Sylvester equation. In the paper, the authors consider a specific case when the solution of the Sylvester equation is an irreversible matrix due to the interconnections of the MIMO channel. The static decoupling model approach is proposed for the problem solution, where the steady-state gain matrix is used as the static decoupler. The case of the irreversible steady-state gain matrix is also considered. It is suggested to use the pseudo-inverse of the steady-state gain matrix for this case. The results are supported by an example.

Introduction. A 2-DOF robotic manipulator affected by unknown external disturbances is a typical MIMO system that can be used to synthesize the new control algorithms. Besides, there are some uncertain parameters that lead to unstable outputs. Furthermore, the hypothesis is that measuring only the outputs causes the higher difficulty of control problems. To solve these problems, an adaptive compensation based on parameterizing disturbances is proposed. The adaptive compensation algorithm is designed using the Sylvester equation. There are cases when the solution of the Sylvester equation is an irreversible matrix due to the interconnections of the channels. In the paper, the authors suggest using the static decoupling model approach to solve the problem, where the steady-state gain matrix is used as the static decoupler. The case of the irreversible steady state gain matrix is also considered in the paper, and it is proposed to use the pseudo-inverse of the steady state gain matrix for this case.

Main part. The adaptive compensation based on parameterizing disturbances of 2-DOF robotic manipulator when measuring only the output is designed as below:

1) Finding the mathematic equations and the state-space model of 2-DOF robotic manipulator using Lagrange equations [1].

In this part, the author uses the Lagrange equation to find the mathematical model of a 2-DOF robotic manipulator. After that, the state-space model after linearization is found, and that will be used in the next part.

2) Parameterizing disturbances and finding the filter model of disturbances [2, 3].

In this part, the author used parameterizing disturbances to find the model of disturbances and the filter model, which will be used to design an adaptive compensator in the next part.

3) Checking the solution of the Sylvester equation is an irreversible matrix or not. If it is an irreversible matrix, the static decoupling model is used [4-10].

In this part, the solution of the Sylvester equation will be checked for inversion. If it is an irreversible matrix, the static decoupling model is used to find the static decoupling model of the system. After that, part 2 is conducted again.

4) Designing the adaptive compensation of external disturbances for 2-DOF robotic manipulator. [2]

In this part, the adaptive compensation of external disturbances for the 2-DOF robotic manipulator is designed. Because it measures only the output, a state observer is also created for all states of the system.

5) Simulating the responses of 2-DOF robotic manipulator with the proposed method.

In this part, an example is illustrated to show the effectiveness of the proposed method.

Conclusion. In this paper, adaptive compensation based on parameterizing disturbances of a 2-DOF robotic manipulator when measuring only the output was proposed. The problem of adaptive compensation has been solved by using the static decoupling method, where the steady-state gain matrix is used as the static decoupler to exclude the influence of interconnections of the channels. The case of the irreversible steady-state gain matrix was also considered. It was suggested to use the pseudo-inverse of the steady-state gain matrix for this case. The simulation results showed the effectiveness of the proposed method.

References:

1. S. M. Mahil, A. Al-Durra. Modeling analysis and simulation of 2-DOF robotic manipulator // 2016 IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS), 2016, pp. 1-4.
2. V. Nikiforov and D. Gerasimov. Adaptive regulation: reference tracking and disturbance rejection // Springer Nature, 2022.
3. Bobtsov A.A., Nikiforov V.O., Pyrkin A.A. Adaptive control of systems with disturbances // - St. Petersburg: ITMO University, 2015. - 126c. (in Russian)
4. Liu, L., Tian, S., Xue, D. et al. A Review of Industrial MIMO Decoupling Control // Int. J. Control Autom. Syst. 17, 2019, pp. 1246-1254.
5. W. Wolovich. Static decoupling // IEEE Transactions on Automatic Control, 1973, vol. 18, no. 5, pp. 536-537.
6. Qing-Guo Wang. Decoupling Control // Springer Berlin, Heidelberg, 2003.
7. T. N. E. Greville. The Pseudoinverse of a Rectangular or Singular Matrix and Its Application to the Solution of Systems of Linear Equations // SIAM Review, 1959, vol. 1, no. 1, pp. 38-43.
8. Golub, G. and Kahan, W. Calculating the Singular Values and Pseudo-Inverse of a Matrix // Journal of the Society for Industrial and Applied Mathematics Series B Numerical Analysis, 1965, vol. 2, no. 2, pp. 205-224.
9. W. A. Harris and T. N. Helvig. Applications of the Pseudoinverse to Modeling // Technometrics, 1966, vol. 8, no. 2, pp. 351-357.
10. Barata, J.C.A., Hussein, M.S. The Moore–Penrose Pseudoinverse: A Tutorial Review of the Theory // Braz J Phys 42, 146–165 (2012).

Hoang D.L. (author) signature

Dudarenko N.A. (scientific supervisor) signature