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Developing of trajectory tracking control method for car-like mobile robots under high order disturbances with modelling compensation

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Abstract
This work suggests a control method for trajectory tracking tasks to be used with car-like mobile robot applications. The suggested strategy depends on disturbances rejection technique and dynamic model compensation and retention to reduce estimation error and increase accuracy. This method considers both low-order and higher-order disturbances by considering both internal model deviation and external disturbances. In addition, this work suggests further developing the strategy by addressing the choice of gains of the observer and controller and how it will affect the performance of the robot.
Keywords
Active disturbance rejection control (ADRC), trajectory tracking, Car-like mobile robots, external disturbances.

Разработка метода управления отслеживанием траектории для мобильных роботов, подобных автомобилям, в условиях возмущений высокого порядка с компенсацией на основе моделирования.

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Аннотация
В данной работе предлагается метод управления для задач отслеживания траектории, предназначенный для использования в приложениях, имитирующих работу мобильного робота-автомобиля. Предложенная стратегия основана на методе подавления возмущений и компенсации и сохранения динамической модели для уменьшения ошибки оценки и повышения точности. Этот метод учитывает как низкопорядковые, так и высокопорядковые возмущения, принимая во внимание как внутренние отклонения модели, так и внешние возмущения. Кроме того, в данной работе предлагается дальнейшее развитие стратегии путем рассмотрения выбора коэффициентов усиления наблюдателя и контроллера и того, как это повлияет на производительность робота.
Ключевые слова
Активное управление подавлением возмущений (ADRC), отслеживание траектории, мобильные роботы типа «автомобиль», внешние возмущения.

Introduction. Trajectory tracking task is one of the most difficult challenges in car-like robots' applications. These challenges become more complicated with the existence of uncertain external disturbances [1], such as slippery surfaces, uneven terrain, frictions, or dynamic obstacles, which decrease tracking performance and affect the stability and safety of the system. To address these problems, several solutions are considered [2], such as using sliding mode control to consider some bounded disturbances or using neural network models for motion control of mobile robots under the condition that all kinematic parameters of the robot are known. Another solution [3] was suggested to use backstepping control combined with developing a disturbance observer for estimation and compensation of the external perturbations considering the case of low-speed scenario which consider kinematic model of

the robot and neglect the effect of the dynamic model. This work suggests a trajectory tracking control method that take into consideration the dynamic model of the robot and proposes an enhanced control strategy, which use active disturbance rejection control (ADRC) method and modify it to consider model compensation with expanded disturbance observation [4]

Main part. To solve the discussed problems which affect the general performance of the mobile robot, several steps have been done by this work, as follows:

1. A study of the kinematic and dynamic models of the car-like mobile robot is done, considering several models (such as Ackerman model, bicycle model) and addressing its constraints and the case where not all kinematic and dynamic models' parameters are known.
2. The effect of external disturbances on the motion of the robot is addressed and combined with model inaccuracies, parameters variations, and unmodeled dynamics as total disturbances to be estimated and cancelled in order to enhance the dynamic performance of the robot.
3. An active disturbance rejection control strategy is considered and modified to deal with total disturbances, by considering model retention in the observer to reduce estimation bias and expanded disturbance observation using higher-order states to improve accuracy.
4. Several experiments are done using MATLAB simulation to test the efficiency of the suggested method.
5. The work also discussed the concept of developing an optimization method for optimizing the choice of gains of the observer and controller and its effect on enhancing the tracking accuracy and speed.

Conclusions. In this work, a control method for trajectory tracking tasks was developed to be used with car-like mobile robot's applications. the suggested strategy depends on disturbances rejection technique and dynamic model compensation and retention to reduce estimation error and increase accuracy. this method allows dealing with low-order and higher-order disturbances by considering both internal model deviation and external disturbances. In addition, this work suggests further developing for the strategy by addressing and considering how the choice of gains of the observer and controller will improve the performance and developing an optimization method for that.

Literature

1. Z. Chen, D. Liao and A. Y. Krasnov, "Adaptive Control of an Uncertain Differential Drive Robot," 2022 8th International Conference on Control Science and Systems Engineering (ICCSSE), Guangzhou, China, 2022, pp. 100-104, doi: 10.1109/ICCSSE55346.2022.10079741.
2. Rokonuzzaman, M., Mohajer, N., Nahavandi, S., & Mohamed, S. (2021). Review and performance evaluation of path tracking controllers of autonomous vehicles. IET Intelligent Transport Systems, 15(5), 646-670. https://doi.org/10.1049/itr2.12051.
3. Zhu, C.; Li, B.; Zhao, C.; Wang, Y. Trajectory Tracking Control of Car-like Mobile Robots Based on Extended State Observer and Backstepping Control. Electronics 2024, 13, 1563. https://doi.org/10.3390/electronics13081563.
4. Zhao C., Li B., Zhu C., Shi W., Zhang X. Lateral Control for UGVs by ADRC With Modeling Compensation and Expanded Disturbance Observation // IEEE Transactions on Industrial Electronics. — 2025. — P. 1–13.