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Design and Simulation of Step-overcoming Driving Mechanism for an Omnidirectional Mobile Robot

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***Abstract*— Recently, robots that deliver goods on behalf of people in urban environments have been widely applied to public. These robots basically perform map-based autonomous navigation and are equipped with local obstacle avoidance functionality. However, there are occasional reports of delivery failures due to obstacles such as curbs and so on. To this end, this study analyzed the mechanical conditions for obstacle overcoming performance to improve the mobility of a wheeled mobile robot and proposed a new driving mechanism that allows step overcoming capability of omnidirectional drive system.**

I. Introduction

Sometimes, a mobile robot becomes unable to move when it encounters an obstacle that is relatively larger than the size of its wheels. To solve this problem, rocker-bogie mechanisms, wheel-leg mechanisms, tracked mechanisms, etc. have been developed [1]. Among these, wheel-leg and tracked mechanisms are rarely applied to outdoor delivery robots due to low durability and low driving efficiency caused by unnecessary friction or vibration. Meanwhile, the rocker-bogie mechanism has the advantage of moving on uneven terrain, but has a limitation in terms of mobility due to skid steering. Some studies have also been conducted to modify shape of wheel or robotic system by adding new motors. However, in this case, there is a problem that robot control becomes slow and complicated and development cost increases. The contributions of this study are as follows. First, kinematic conditions for a wheeled mobile robot to overcome a curb obstacle were derived. Second, through this analysis, a new omnidirectional driving mechanism suitable for overcoming curbs was designed. Lastly, the overcoming performance of the developed movement mechanism according to obstacle height was verified with dynamics simulation.

II. Step-overcoming Kinematics of a Wheeled Robot

A. Font wheel lift condition

When a wheeled robot faces a curb, the kinematic conditions for the front wheels to be lifted can be derived as (1). In (1), μ is the friction coefficient, and other parameters are shown in Fig. 1.

$$\frac{r}{l} > \frac{\cos\alpha - 2K\sin\alpha - 2\mu K\cos\alpha}{K\cos\alpha - \mu K\sin\alpha + \mu K}, \quad K = \frac{\mu}{1+\mu^2}. \tag{1}$$

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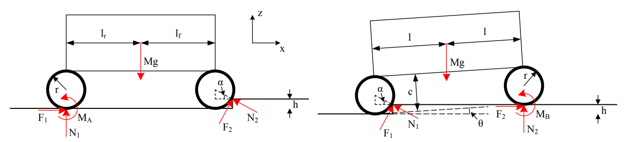

Figure 1. Free-body-diagram of a wheeled robot overcoming a curb (left: front wheel contact, right: rear wheel contact).

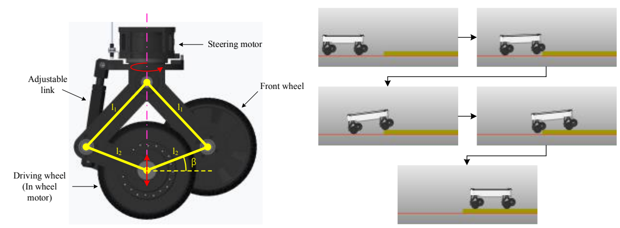

Figure 2. Proposed driving mechanism(left) and curb overcoming simulation result(right).

B. Rear wheel lift condition

The kinematic conditions for the robot's rear wheels to overcome the curb are as follows.

$$\frac{r}{l} < \frac{-\cos\theta + 2K\cos\theta\tan\alpha + 2\mu K\cos\theta}{K\sin\theta\tan\alpha + \mu K\sin\theta + K\sin\alpha + \mu K\cos\alpha}. \tag{2}$$

III. Step-overcoming Mechanism Design

In order for a wheeled robot to overcome a curb, both (1) and (2) must be satisfied. For this purpose, in this study, a driving mechanism that can control the contact angle α was designed as shown in Fig. 2. The proposed mechanism was verified through dynamics simulation as the robot can stably overcome a curb obstacle as high as the radius of the wheel.

IV. Conclusion

In this paper, we propose a new driving mechanism to overcome a curb obstacle for an outdoor delivery robot, which is being introduced to handle the recently increasing delivery logistics. Through dynamic simulation of a robot using the proposed mechanism, it was confirmed that it is possible to overcome an obstacle of same height as the wheel radius. In the future, we plan to manufacture the proposed mobile robot and verify its obstacle-overcoming performance through experiments.

References

[1] Seo, T., Ryu, S., Won, J. H., Kim, Y., Kim, H. S., “Stair-climbing Robots: a Review on Mechanism, Sensing, and Performance Evaluation,” *IEEE Access*, vol. 11, 2023, pp. 60539-60561.