2024 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)
July 15-19, 2024. Boston, MA, USA

Step-up wheels: mechanical soluation of novel wheel design for overcoming steps

Woojae Lee[1,2], Taehyun Kim[2], Jeongeun Kim[2] and TaeWon Seo[1,*], *Senior Member, IEEE*

***Abstract*— Wheeled mobile service robots are increasingly used in restaurants, factories, and homes in various ways. Currently, autonomous mobile robots are used to move heavy weight goods to specific points in industrial environments such as factories. In everyday life, it is widely applied in the personal service sector, such as delivery service. This study proposes a wheel mechanism based on a joint link. We propose a step-up wheels that show the ability to overcome steps higher than the wheel diameter of a mobile robot through vertical force conversion. The concept of link-based reaction step-up wheels mechanism is introduced, and the constraints and design variables reviewed in the system configuration are examined. The mobile robot's ability to climb high stairs is improved by converting drive into vertical force using sub-wheels connected to the manual joints of the wheels. By delivering the body of the wheel drive robot through the converted vertical reaction force, the ability to climb steps is improved using the reaction force of the steps. The kinematic analysis and optimized design variables according to the link configuration and constraints of the wheel system are described. The vertical force required to lift the robot to the ground is maximized through the optimized variables. It provides the driving force and simulation data necessary to overcome the steps of the mobile robot through the previous analysis process. Experiments were conducted in various environments to prove the ability to overcome steps through prototype robot production. In conclusion, it was confirmed that the improvement of the step-overcoming performance was confirmed by changing the horizontal passive force of the robot generated during driving to vertical force**

I. INTRODUCTION

Conventional mobile robots have been studied for overcoming various obstacles. Mobile robots with wheels have difficulty overcoming high steps, especially in service-oriented tasks such as serving and delivery. To improve the mobile robot's ability to overcome steps, increasing the size of the wheels is the solution, but in turn, it makes the robot system bigger. To overcome this, we propose a new caster mechanism that improves the ability to overcome steps without larger wheels. These systems increase the size and number of wheels, and mobile robot systems become complicated. In order to overcome the shortcomings of existing mobile robots and improve the performance of overcoming obstacles, this paper proposes step-up wheels.

*This work was funded by HD Hyundai Robotics.(Corresponding author: TaeWon Seo)

[1]W. Lee and T. Seo are with the school of Mechanical Convergence Engineering, Hanyang University, Seoul 04763, Republic of Korea (e-mail : yesterday451@hanyang.ac.kr, taewonseo@hanyang.ac.kr)

[2]W. Lee, T. Kim and J. Kim are researchers at HD Hyundai Robotics, Gyeonggi 13553, Republic of Korea (e-mail : kth81@hd.com, vewry12@hd.com)

II. STEP-UP WHEELS CONCEPT AND DESING

A. Step-up Wheels Concept

Existing mobile robots have a limited height to overcome the step depending on the diameter of the wheel. To improve the stability of overcoming the step, we design a link mechanism by which sub-wheel can be driven. The driving force of the main wheel generated by the mobile robot is converted into the vertical force of the sub-wheel to lift the main wheel from the ground while pressing the upper surface of the step. The proposed wheel mechanism improves the step-over performance of the wheel by converting the horizontal reaction force into the vertical reaction force. It allows you to overcome a high level of more than 50% of the wheel diameter.

B. Mechanism Design

When the driven wheel contacts the vertical surface of the high obstacle, the sub-wheel moves in the direction of gravity through the connected link. The driving force is deformed in the vertical direction. A system is implemented in which the entire mobile robot overcomes the step while pressing the upper surface of the step that the sub-wheel overcomes. Kinetic, design parameters analysis was performed to confirm the transition of the force of the sub-wheel to the vertical force. Through the optimization process for the design variable of each link constituting the step-up wheels, the design was carried out in a size that could replace the existing system. The verification of the vertical force pressing the upper surface of the step generated through the simulation process and the deformation of the force according to the variables were conducted.

III. CONCLUSIONS

The proposed step-up wheels propose an improvement mechanism for both driving wheel and non-driving caster wheel systems. To implement the step-up wheels system, the approach was verified in a kinematic analysis and simulation environment. In conclusion, by converting the horizontal passive force generated by the robot during driving into a vertical force using a sub-wheel, it was possible to confirm the improved step-overcoming performance compared to a system with wheels alone. Experimentally, it was verified to overcome a high stage of more than 50% of the wheel diameter. It is configured with the same system size as the wheel system of the existing mobile robot. It is possible to improve the step-up performance by changing the wheel system of the existing mobile robot to step-up wheels.