Proceedings of 2017 IEEE
International Conference on Mechatronics and Automation
August 6 - 9, Takamatsu, Japan

Design and Development of Steered Active Wheel Casters and Its Application

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***Abstract*— Recently, omnidirectional powered-wheelchairs that have high mobility at a narrow space or a place with many obstacles are studied actively. Many of conventional omnidirectional mechanisms use special wheel mechanisms, such as a mecanum wheel etc. However, this mechanism is unsuitable for use in powered-wheelchairs, because of having problems, such as serious vibrations while moving, low loadability, etc. In previous studies, an active dualwheel caster that can use general rubber tires and an omnidirectional mobile platform using several such assemblies have been developed. However, there is a problem that omnidirectional movement becomes impossible, when one of wheels in this assembly would run aground to a level difference or idle. The objective of this study is to develop an omnidirectional mobile platform to solve this problem, where the platform uses several steered active wheel caster assemblies. Also, a rocker-bogie system that is a kind of suspension systems is used for the platform to improve traveling performance. In this paper, we give an overview of the steered active wheel caster assembly and propose a mobile platform, and describe the production process and experimental results.**

***Index Terms*— Steered Active Caster Assembly, Omnidirectional, Rocker-bogie system.**

I. Introduction

In Japan, the ratio of elderly person is more than 21 of total population [1]. From such a social background, the demand for welfare tools increases so as to realize an objective of supporting the life of elderly persons. Particularly, powered wheelchairs are greatly needed to assist the movement of elderly person. However, a general powered wheel chair needs a wide space for a quick turn, when changing the direction. Therefore, omnidirectional wheelchairs are studied actively, because its high mobility at a narrow space or a place with many obstacles [2]. Conventional omnidirectional platforms to be used for omnidirectional mobile wheel chairs have a special wheel mechanism, such as mecanam wheels, and spherical wheels, etc [3]. However, these mechanisms have problems such as serious vibrations while moving, low loadability, etc. Also, these have a low ability in getting over a level difference. From this point of view, Han et al. [4] have proposed an omnidirectional mobile robot using the “active dual-wheel caster assemblies” ,which can achieve the omnidirectional movement using common wheels, such as rubber tires. However, there is a problem that omnidirectional movement becomes impossible, when one of wheels in this assembly would run aground to a level difference or idles. In this study, it is aimed at developing an omnidirectional mobile platform to solve this problem. A steered active wheel caster assembly [5] is adopted in the omnidirectional mechanism. This imitates a caster, and has two motors to drive the wheel and steering. In addition, the usefulness of an omnidirectional mobile robot based on this was confirmed by Wada et al [6]. However, this study did not consider to ride a step in a public road, so that it needs to improve a travel performance to use the omnidirectional mobile platform. Therefore a locker-bogie system that is a kind of suspension system is used for its objective. Therefore a locker-bogie system that is a kind of suspension system is used for the platform. In this paper, we give an overview of the steered active wheel caster assembly and the proposed mobile platform, and describe the production process and experimental results.

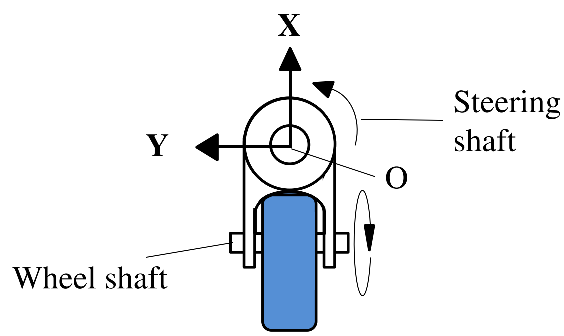


Fig. 1. Upper view of a Steered Active Wheel Caster

II. STEERED ACTIVE WHEEL CASTER ASSEMBLY

Fig. 1 shows the upper view of a steered active wheel caster assembly. This assembly has two motors to be used for steering and driving. This places a driving shaft and a steering shaft at the interval of a constant distance. Then, the translation speed generated around the steering shaft by steering always become the right angle direction with respect

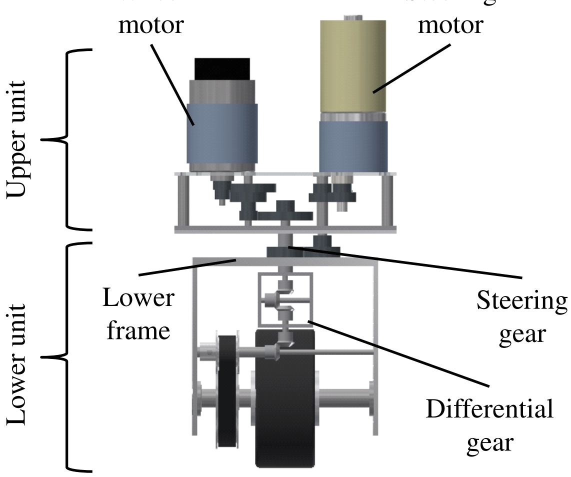


Fig. 2. Structure of the new Steered Active Wheel Caster

to the wheel. Thus, these two velocity vectors are always orthogonal. Therefore, it is possible to produce a velocity vector with any direction and its size on the steering shaft by controlling these two velocity vectors. A conventional assembly has a problem that the rotation of steering shaft affects the driving of the wheel, and solves this problem by control. Therefore, there exists a demerit that the control becomes complicated. Fig. 2 shows the structure of a new steered active wheel caster assembly. The gear to be used for steering is fixed to the lower frame of such a steered active wheel caster assembly. This gear is hollow, and a drive shaft is penetrated into it. An interference to the wheel rotation due to the steering motor is revised by a differential gear mechanisms.

III. Omnidirectional Mobile Platform with Steered Active Wheel Caster Assemblies

A. Conditions to be Considered

It is restricted, from the Road Traffic Law [7], that the size of powered wheel chairs is less than 1200 mm in length, 700 mm in width, and 1090 mm in height. Furthermore, it is set that the boundary steps of the sidewalk and the road are less than 50 mm. Therefore, these matters must be considered in the development of an omnidirectional wheel chair and it needs an ability in getting over a step difference more than 50 mm. Also in this study, we produce a small sized prototype to prove the usefulness of omnidirectional mobile platforms using steered active casters. This prototype is 485 mm in length, 385 mm in width and 244.5 mm in height, whose diameter of the wheel is 75mm.

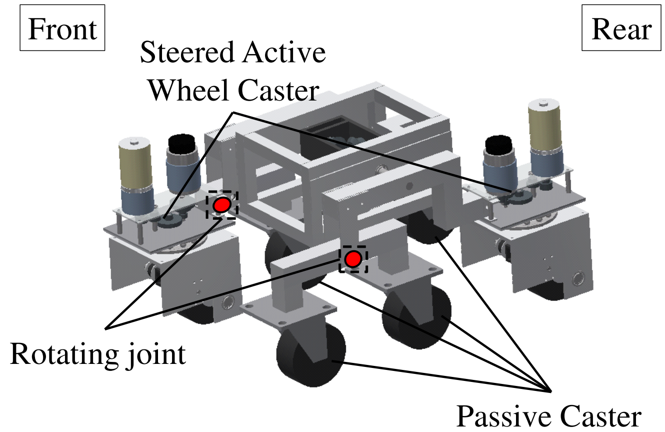


Fig. 3. Whole view of the omnidirectional mobile platform

B. Designed Omnidirectional Mobile Platform

The robot developed in the preceding study of Wada et al. combined three steered active casters so that they constituted an equilateral triangle at the bottom place of the robot. However, this robot does not consider the riding at a human, so that there are some problems, such as stability when getting over a step difference. Therefore, the mobile platform to be produced adopts a locker-bogie suspension mechanism described later. Fig. 3 shows the total view of the omnidirectional mobile platform proposed here. It is assumed that a bogie link set in front for convenience and a locker link is set in rear. The omnidirectional movement is achieved by setting one steered active caster as the right front wheel and the left rear wheel in the mobile platform, respectively.

C. Locker-bogie System

1) Basic Structure: In this study, a locker-bogie system is used as a suspension system. As characteristics of this system, it is easy to realize the downsizing and lightweight of the body because this system does not use any actuators. The locker-bogie system proposed here has six wheels, where the locker link and the bogie link are coupled by a rotary joint. The rotary joint of the mobile platform can turn each side independently. Therefore, it can realize situation where all driving wheels are grounded, even when one of both active wheels would be running aground a step so that it is possible of achieving an omnidirectional motion. Therefore, it needs to determine the arm length shown in Fig. 4 from the balance of a moment. Because of the characteristics of the rocker-bogie mechanism, the improvement of running performance can be expected when a load equally is applied to the six wheels. Parameters related to the omnidirectional mobile platform are shown below.

- $A1$: Distance from a front wheel to a rotary joint of the locker-bogie mechanism

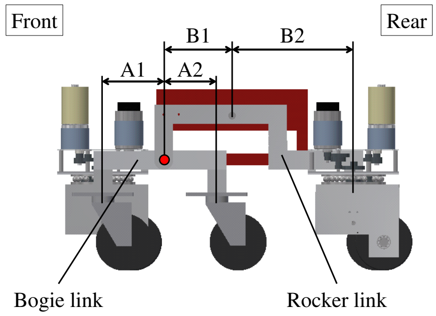


Fig. 4. Side view of the mobile platform

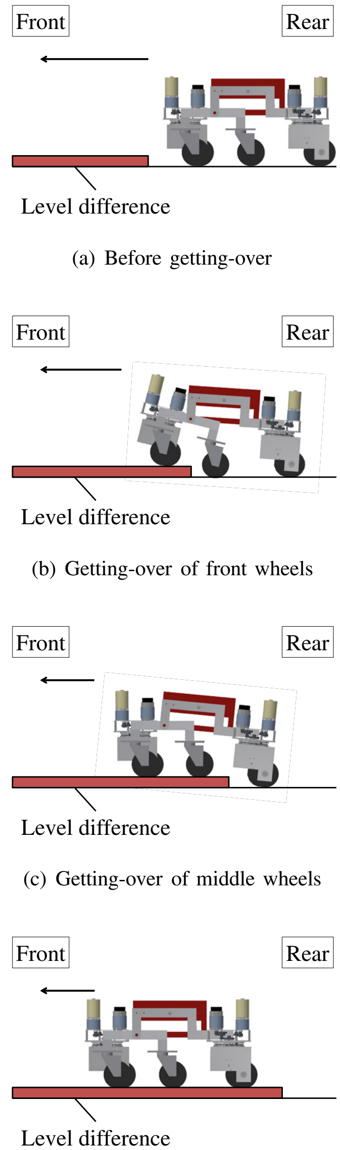
- $A2$: Distance from the rotary joint of the locker bogie mechanism to the middle wheel
- $B1$: Distance from the rotary joint of the rocker bogie mechanism to the center of gravity of the robot
- $B2$: Distance from the center of gravity of the robot to the rear wheel

Assuming that the mass of the steered active caster assembly is 5 kg and the weight of the passenger is 60 kg, it is possible to apply the same load to each of the six wheels, if the ratio of the parameters is set as follows.

$$
\begin{aligned}
A1 : A2 &= 76 : 66 \\
B1 : B2 &= 76 : 137
\end{aligned}
$$

2) Operation Principle: Fig. 5 shows the behavior of getting over a level difference that is taken by a robot using the locker-bogie system. In this case, the rotary joint which couples a bogie link and a locker link rotate freely, so that this mobile platform can get over a level difference under the condition that all wheels are grounded.

3) Stabilization of the Main Body: Fig. 6 shows the top view of the mobile platform. The proposed mobile platform mounts a differential gear mechanism at the center of the main body, to connect the locker bogie systems placed at the right and left sides. Since the difference gear mechanism faces the center of each inclination of both locker-bogie systems, the main body can keep a stable state even if each locker-bogie system tilts in a different angle.



(a) Before getting-over

(b) Getting-over of front wheels

(c) Getting-over of middle wheels

(d) After getting-over

Fig. 5. Behavior of getting-over

IV. Development of a Prototype Mobile Platform

A. Development of the steered active wheel caster assembly

Fig. 7 shows the steered active wheel caster assembly developed in this study. Since the driving motor is attached to the main body, it needs to consider the problem related to the communication line to drive a tire. The developed assembly transmits the torque by gears, instead of using the slip-ring. The problem related to the communication line is solved by this way. The mobile platform achieves an omnidirectional movement by using multiple steered active wheel caster assemblies. To this end, these two assemblies are produced in this study.

B. Robot Components

Fig. 8 shows the system components of the proposed assembly. The motor is connected to a microcontroller, GR-SAKURA, through a motor driver. An incremental encoder and an absolute encoder are connected to a comparator board. The incremental encoder is used for measuring the rotational speed of the wheel of this assembly. The absolute encoder is used for measuring the steering angle of this assembly.

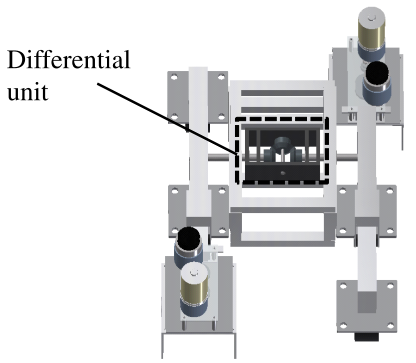


Fig. 6. Upperview of the mobile platform

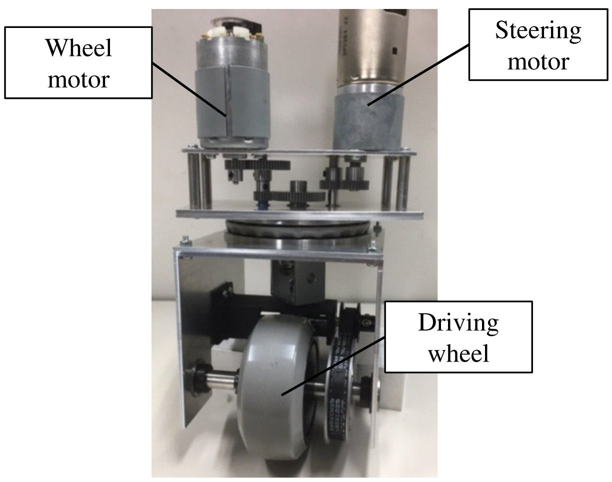


Fig. 7. Appearance of the assembly

This IC distinguishes the High voltage or Low voltage in the incremental encoder. The value of the encoder is sent to the UDCNT-ABSENC board, which converts the value of the encoder into a serial value, via this board.

C. Parts Selection

1) DC Motor: Assuming that the maximum weight of the prototype platform including a driver is 60 kg, the running torque in maximum is calculated as 39.94 kgf·cm. From this fact, the RS-645VW made by Mabuchi Motor Corporation was selected as DC motor, whose torque with the reduction ratio of 27 was 55.86 kgf·cm. Therefore, it can be confirmed that the selected motor has sufficient performance. In addition, this motor is equipped with an incremental encoder. Therefore, it need not prepare some parts and mechanisms for measuring the rotational speed of the wheel.

2) Microcontroller: A microcontroller uses the GR-SAKURA microcontroller board made by Renesas Electronics Corporation. The GR-SAKURA is equipped with an RX63N microcontroller, whose clock speed is 96 MHz. In addition, since this microcontroller has a pulse output function, PWM control of the DC motor is possible. Therefore, it is considered to have sufficient performance to be used for the omnidirectional mobile platform.

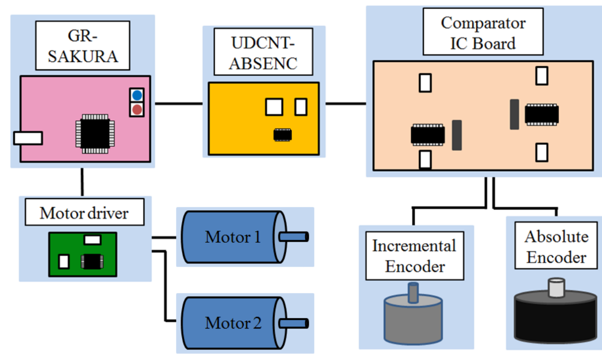


Fig. 8. Robot componet

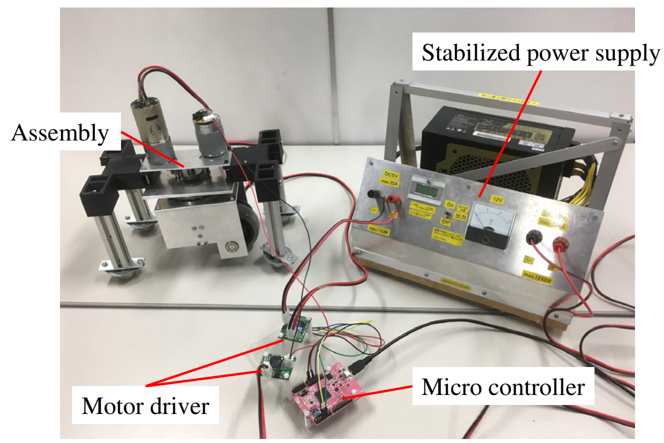


Fig. 9. Experimental device

V. Experiments

A. Experimental Objective

To use a steered active wheel caster as an omnidirectional moving mechanism, it needs to generate a velocity vector in two degrees of freedom (DOFs) in the X- and Y-axis directions immediately. The purpose of this experiment is to confirm whether a velocity vector in 2DOFs is generated on the steering shaft of this assembly, by performing a translational motion and a steering, which are the fundamental behaviors of steered active caster assembly produced here.

B. Experimental Conditions

Fig.9 shows the experimental device. The experimental device consists of a steered active wheel caster assembly, a stabilization power supply, a micro controller, and a motor driver. Since any power supply is not loaded in the assembly, the electricity is supplied from the stabilization power supply.

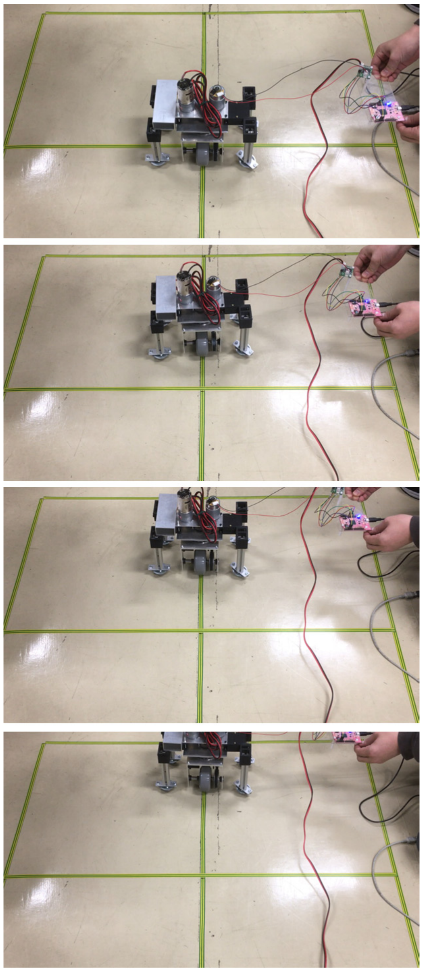


Fig. 10. Translation

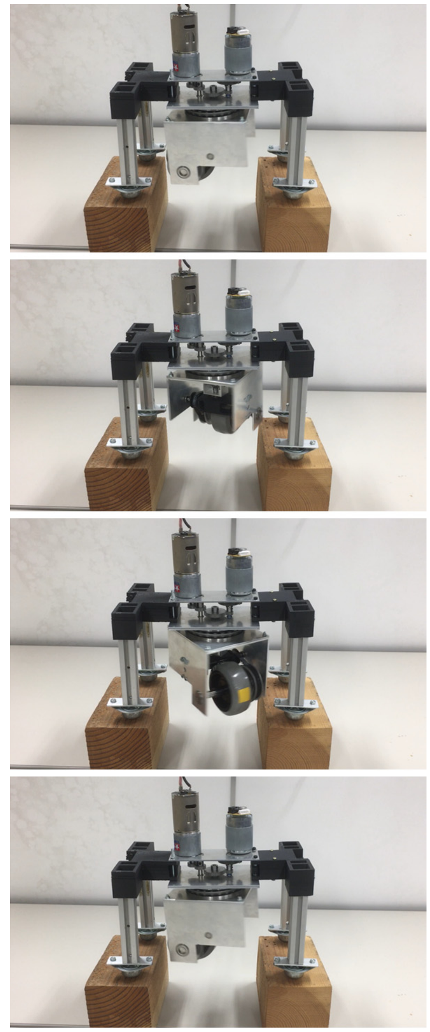


Fig. 11. Steering

Each cable is always to be a superfluity state so that they do not affect the assembly motion.

C. Experimental Method

The experiment is conducted, under the assumptive that the floor is smooth and that there are no obstacles. The speed control of the DC motor mounted on the assembly is conducted using a motor driver. Each motion is tried more than five times, and it is verified whether the application to a omnidirectional mobile platform is possible. Each experimental method is shown below.

- translational motion experiment: In translational motion experiment, a PWM value is input into the driving motor.The steering motor is not connected to the power supply, so as not to make it work. Furthermore, a tape is pasted in the floor as a base line.
- steering experiment: In the steering experiment, a PWM value is input into a steering motor, where the driving motor is not connected to the power supply so as not to make it work. Since a friction occurs if the drive wheel is in contact with the ground, only the auxiliary wheels are grounded, i.e., the experiment is conducted under the situation where the drive wheel is not ground.

D. Experimental Results

Fig. 10 shows the situation of a translational motion, and Fig. 11 shows that of steering.

E. Considerations

It is confirmed that the assembly developed realizes the translational motion and steering. Thus, this assembly can be applied to an omnidirectional mobile platform. However, since many gears are used for this assembly, several problems such as backlash and influence on gear meshing due to vibrations while moving are considered, so that it needs a treatment to overcome them.

VI. CONCLUSION

In this paper, we have described an overview of the proposed active caster mechanism with steering, and an omnidirectional vehicle by applying it. As future work, a feedback control method will be introduced for controlling the rotation speed of motors by measuring the number of revolutions of the motor. We will successively construct an omnidirectional mobile platform using the steered active wheel caster assembly developed here.

REFERENCES

[1] Statistic Bureau, Ministry of Internal Affairs and Communications, "demographic statistics," 2016.

[2] H. Kitagawa, T. Beppu, Y. Ohno, T. Miyoshi, and K. Terashima "Motion control of omni-directional mobile wheelchair considering user's comfort," *in Proc. of the Robotics of Society*, vol. 22, no. 7, 2012. pp. 142–152,

[3] O. Diegel, A. Badve, G. Bright, J. Potgieter, and S. Tlale, "Improved Mecanum Wheel Design for Omni-directional Robots," *in Proc. of Australasian Conference on Robotics and Automation* 2002, pp. 117–121.

[4] F. Han, T. Yamada, K. Watanabe, and K. Izumi, "An omnidirectional mobile robot using multiple active dual-wheel caster assemblies," *Trans. of the Japan Society of Mechanical Engineers, Series C*, vol. 67, no. 653, 2012, pp. 154–161.

[5] M. Wada, "Modeling and control of omnidirectional mobile robots with active casters,"*in Proc. of the Robotics of Society*, vol. 25, no. 7, 2007, pp. 1100–1107.

[6] M. Wada, "Development of a holonomic and omnidirectional mobile robot,"*in Proc. of the Robotics of Society*, vol. 15, no. 8, 1997, pp. 1139–1146.

[7] Ministry of Land, Infrastructure, Transport and Tourisms "Road traffic law enforcement regulations, 1–4,"