

# Designing Practical Omni-directional Mobile Module in the Robot Hardware Platform for Common Use

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**Abstract:** As a holonomic omni-directional mobile robot is useful with its high mobility in a narrow or crowded area, it has been studied for a long time. But until now most of the omni-directional mobile robot developed in the laboratory level, universities and research institutes for study. Commercially available omni-directional mobile robots are mostly educational robots, toy robots, and omni-directional forklift. This study looks forward to presents commercialization of omni-directional mobile robot with many advantages and developed prototype. In this paper, we introduce the details of this progression and use it throughout the experiment and practical application proved.

**Keywords:** Omni-directional, Mobile robot, Practical design, Modularization

## I. INTRODUCTION

Differential drive, most mobile robots are used in, have benefits such as rotation in place and simple structure, but cannot move laterally and have restrictions on the movement. Omni-directional steering mechanism can be applied to perform tasks in a small, complex environment due to the ability of 3DoF movement(front and back, left and right, rotated), which makes possible to travel in any direction from the position, in two-dimensional planar.

Omni-directional mechanism is largely divided into using a structure without omni-directional wheels and using omni-directional wheels. There are several types of omni-directional wheels like universal wheel, mecanum wheel, double wheel, alternate wheel, half wheel, orthogonal wheel, ball wheel, etc[1][2][3].

In Synchro-drive mechanism, the representatives of the structural omni-directional implementation, each wheel drives and steers at the same time. In other words, a driving motor drives all wheels and a steering motor steers all wheel-assemblies. The advantage of this structure, all wheel driving force is equal which allows excellent friction and odometry performance. Little couple relation between the driving and steering can minimize the heading error and make easier to control. And because there is no turning radius, learn to operability. Less destructive force against the floor lets high-efficient and also reduces power consumption[4][5].

The concept of the omni-directional movement, which has already been established long ago, has many

advantages, but it is a matter of practicality and there are not commercially available. In this paper, the structural simplicity, usability, scalability and modular design to move forward by suggesting consideration commonization robot platform can be used as the possibility of getting the look. In Chapter 2, design direction, simulation processes are described to explain the overall concept. The component selection process, mechanical designing are depicted in Chapter 3. In Chapter 4, the performance and specifications are verified through the experiment with a prototype.

## II. CONCEPTUAL DESIGN

### 1. Point of Design

Products to be used can be applied to a variety of forms, and compact size, reliability, scalability and direction were the main design.

First, moving from general indoor environment, there is no problem, because you should not bad-efficient to forward the implementation of structural and slip ring in order to simplify the structure was used actively. Most existing methods of synchro-drive mobile robot with a driving axis to synchronize steer axis and the axis between the two couple to resolve the problem requires a complex mechanical mechanism[4]. Due to its complexity, this approach reduces efficiency and reliability were also problems. Low contact resistance was used as a communication line, even when there are no problems using the slip ring to allow rotation of each

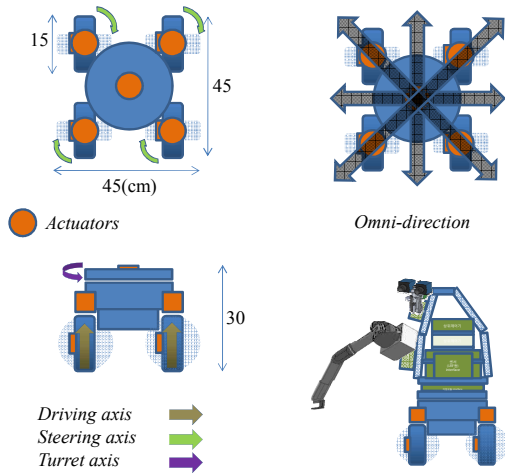


Fig. 1. Conceptual Design of Omni-directional Mobile Module

axis, the infinite couple minor fixes and simplification of power delivery for each axis are available.

In addition to the scalability of the main drive sub-module a variety of sizes to accommodate the demand was for. Payload, even if a similar application area of robots to the base part may differ. In such a case the size of the base plate needed to produce the driving axis sub-module by attaching the desired shape of the omni-directional mobile base can be built.

Payload of a human scale dual arm, head, battery, 2~3kg lightweight enough to mount around the body is 65cm wide and narrow areas of the body moves without change of direction is possible, the size of a person's normal walking speed (3km/h) was faster than the speed targets. Wheel configuration hill driving or high speed and cause to stability in the face of slowing excellent 4-wheel synchronous structure was adopted as shown in Fig. 1.

Homing direction for reducing time-axis turret axis absolute encoder is used. If you use the proximity sensor and because there is no absolute position in your robot, the robot may move up to 180 degrees and homing time can take a very long time.

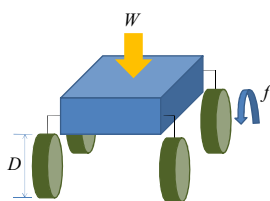


Fig. 2. Basic Structure of Omni-directional Mobile Module

## 2. Specifications of Joints

Specifications for a driving axis are obtained as following.

$$\begin{aligned} \tau &= \tau_a + \tau_m \\ \tau_a &= \frac{J}{g} \times \pi \times \frac{f}{t} \\ &= \frac{3000kg \cdot cm}{980cm/sec^2} \cdot \frac{\pi \times 1.59rev/sec}{0.5sec} \\ &= 30.5kg \cdot cm \\ \tau_m &= \mu WD / 8 \\ &= (0.1 \times 60kg \times 20cm) / 8 = 15kg \cdot cm \\ \tau &= 45.5kg \cdot cm = 4.46N \cdot m \end{aligned}$$

,where  $\tau_a$  is acceleration torque,  $\tau_m$  is friction torque, moment of inertia  $J = WD^2 / 8 = 60kg \times (20cm)^2 / 8 = 3000kg \cdot cm^2$ , desired angular velocity  $f = 1.59rev/sec$  (linear velocity 1m/sec), desired acceleration time  $t = 0.5sec$ ,  $W$  is weight of load and  $D$  is diameter of a wheel.(Fig.2)

Joint specifications are calculated from the upper formulas like 4.46N·m, 128rpm for a driving axis, 3.5N·m, 120rpm for a steering axis, and 7.96N·m, 60rpm for a turret axis.

## 3. Simulation

As shown in Fig.3, a commercial simulator (RecurDyn V7R1) was used to validate the joint specification calculated from the formula in Chapter II-2. The results derive the required joint torque and the current is consumed.

Fig.4 shows the result of simulation. Besides the result of steering axis, which might be caused by the friction condition, we got the similar values to one of the formula.

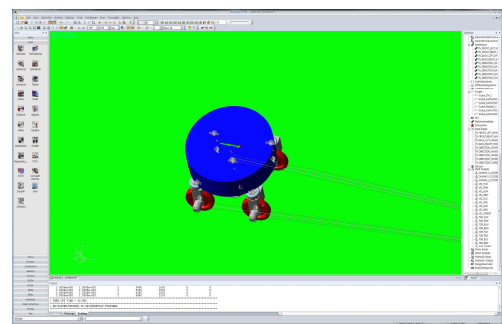


Fig.3. Simulation with RecurDyn

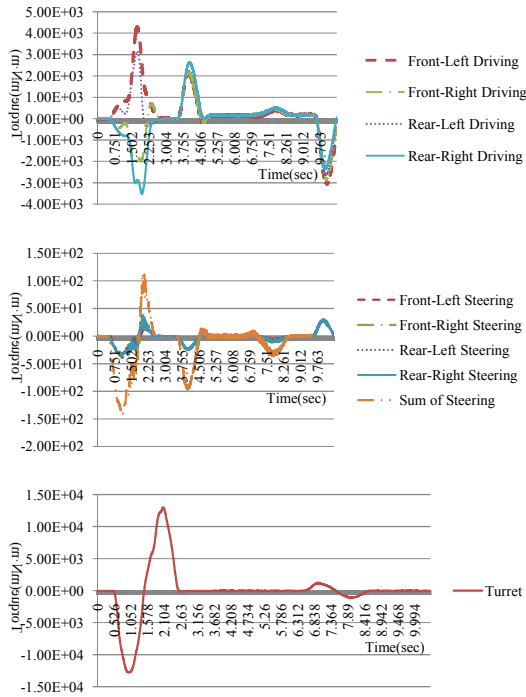


Fig.4. Results of Simulation

### III. DETAILED DESIGN

#### 1. Mechanical Design

The selection of each component was carried out on the basis of joint specification obtained from the simulation and the formula. Motors of *maxon motor Co., Ltd.* are used for the purpose of the small volume over power. For the driving axis, *EC-powermax*, which has small diameter and is BLDC-typed, is used to be mounted inside the wheel and for compact design. For the reduction gear of steering axis, a *SHD* model of *Harmonic Drive Systems Inc.* is selected, because it has lower overall height, but a little defect on the precision. For the slip ring, one of the important elements for the simplification of the structure, *630K* model of *Mercotac Inc.* is used due to relatively small contact resistance. However, for the steering axis, *SRS* model of *Rotac Inc.* is selected, because there is not enough space. The wheel made from the material of thermoplastic rubber elastomer tread is used, because there should be small friction with ground in steering, and small reaction force. The details are shown in Table 1.

CAD image of three kinds of sub-modules are shown in Fig.5. The used tool is *Solid Edge ST2*.

Table 1. Specifications of Parts

Items	Manufacturer	Model
Actuation	Driving axis	EC-powermax 30 (200W) + GP32C(66:1)
	Directing axis	Maxon motor, HDS EC-powermax 30 (200W) + SHD 14(50:1) + pulley(1.5:1)
	Turret axis	EC-powermax 30 (200W) + SHD 17(100:1) + pulley(1.2:1)
Slip ring	Directing axis	Rotac SRS1802-12 (12 conductors)
	Turret axis	Mercotac 630K (6 conductors)
Wheel	Blickle	TPA 150/12K (Dia. 150mm)
Abs. encoder	For origin US Digital	MAE3 (12bit/turn)
Motor controller	Solubot Co. Ltd.	BLDC 10A 1-axis controller (CAN interface)

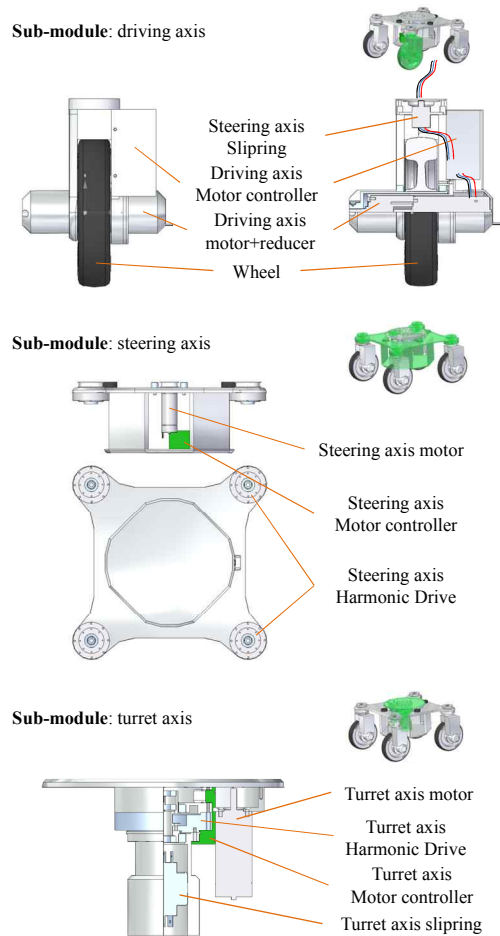


Fig.5. Sub-modules and Detailed Structure

## 2. Electrical Design

Components of this mobile module are divided by their functions like motion controllers, absolute encoders, IMU sensors, and so on. CAN interface and CANopen communication protocol are used for connecting with one another as shown in Fig. 6.

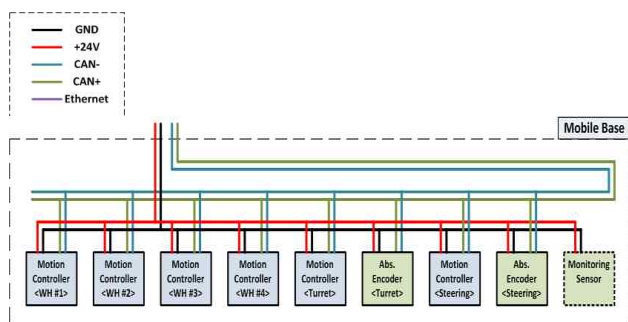


Fig.6. Electrical structure

## IV. EXPERIMENT

The experiment is carried out to verify the achievement of the desired specifications in payload and velocity, which are main indicator. For the experiment of payload, the frame is mounted on the mobile module and the load, including the battery, of 50kg is added as shown in Fig.8. In this state, round trip moving test is progressed in the velocity of 1m/sec in three meters intervals like Fig.8.



Fig. 7. Prototype of Omni-directional Mobile Module

Table 2. Specifications of Module

	Specifications
wheel config.	omni-directional
Max. velocity(m/sec)	1
Payload(kg)	50
Weight(kg)	16.2
Dimension(cm)	45×45×23.5
Communication	CAN

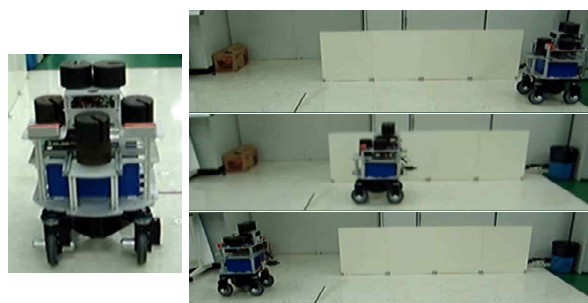


Fig.8. Payload Test of the Mobile Module

## V. CONCLUSION

In this paper, a practical form of omni-directional mobile module is described in the design and prototype. It is true that the omni-directional mobile module is useful, but complex and expensive relatively to the differential drive mobile robot. However, as proposed in this paper, if the structure is simplified by using the parts helpful for simplifying aggressively and the modularization is considered for the scalability, it is possible to produce on a large scale by being able to respond to the various demands, to decrease the cost of manufacturing, and to be used widely in the end.

In the near future, the mobile module designed in this study will be used for research of robot hardware platform in common use, and should be improved for the reliability by the more experiment and complements.

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