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Development of an omnidirectional Automated Guided Vehicle with MY3 wheels☆

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Summary This paper presents an omnidirectional Automated Guided Vehicle (AGV) with a novel omnidirectional wheel named MY3 wheel. Due to the special structure and material of the MY3 wheel, the AGV has full three DOFs in the motion plane and good capabilities of load carrying and slip resisting. In addition, the kinematic model of the AGV is derived, and the guiding method that can make the AGV to follow a specified path is established. Finally, experiments are performed to verify the kinematic model and guiding method.

Introduction

An Automated Guided Vehicle (AGV) is a driverless transport system used for horizontal movement of materials (Vis, 2004). Nowadays, AGVs have been widely used in industrial applications such as transporting materials around manufacturing facilities or warehouses automatically to increase efficiency and reduce costs (Ronzoni et al., 2011; Bui et al., 2013; Kirsch et al., 2012). In addition, AGVs have also showed great potential value in office, domestic, and outdoor services (Tsumura, 1994; Vamossy et al., 2014).

For most of the existing AGVs, the differential driving method is adopted due to its simplicity and zero-radius turning. However, the differential driving method cannot work effectively in the narrow space, because it cannot perform the lateral translation (Ronzoni et al., 2011; Bui et al., 2013). In order to enable AGVs to have full three DOFs in the motion plane (two translations and one rotation), some researchers have tried to equip AGVs with omnidirectional wheels to construct omnidirectional AGVs (Kim et al., 2012; Kirsch et al., 2012; Kumra et al., 2012).

A variety of omnidirectional wheels have been proposed over the past few decades, and most of them are designed based on the concept that achieving the active motion in one direction and allowing the passive motion in another direction. A general type of the omnidirectional wheel is an assembly of a traditional wheel and some passive rollers mounted at the periphery such as the Mecanum wheel (Muir

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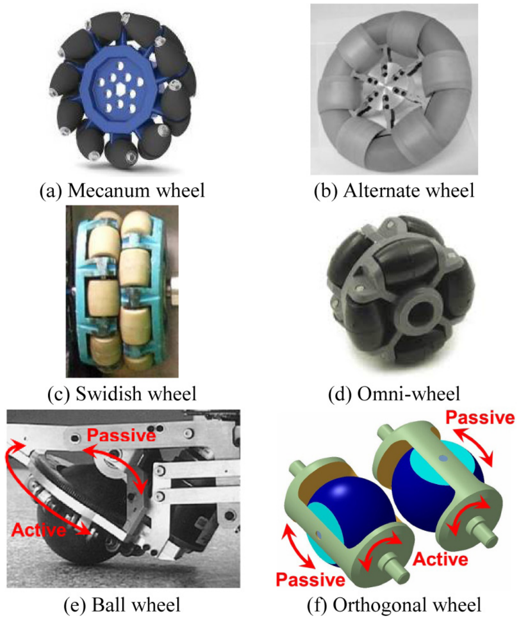

Figure 1 Omnidirectional wheels.

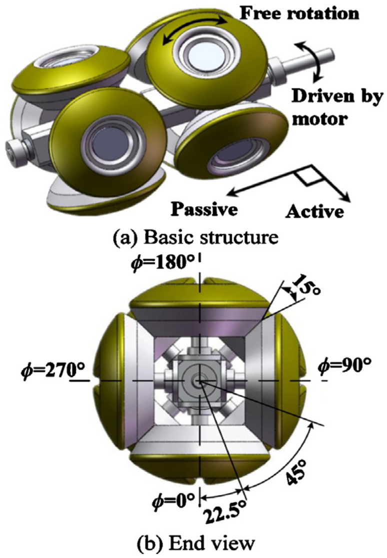

Figure 2 MY3 wheel.

and Neuman, 1987), Alternate wheel (Byun and Song, 2003), Swedish wheel (Indiveri, 2009), and Omni-wheel (Asama et al., 1995) (shown in Fig. 1a—d). This type of wheel can accomplish omnidirectional motions, but the mechanism has a low load carrying capability and is sensitive to dirt and fragments on the ground. Wada and Asada proposed an omnidirectional ball wheel and applied it to wheelchairs (Wada and Asada, 1999) (shown in Fig. 1e). The ball wheel is very flexible on the ground, but the mechanism is complex. Pin and Killough proposed the ''orthogonal-wheel'' concept and two major wheel assemblies (Pin and Killough, 1994) (shown in Fig. 1f). The mechanism of the orthogonal-wheel is compact, but the load carrying capability also needs to be improved.

In our previous work, a novel omnidirectional wheel named MY wheel has been proposed (Ye and Ma, 2009; Ye et al., 2012, 2014). Compared to conventional omnidirectional wheels, the MY wheel is insensitive to dirt and fragments on the ground and has larger load carrying capability. In this paper, an omnidirectional AGV with the third generation of the MY wheel named MY3 wheel is proposed, and the remainder of this paper is organized as follows. In Section ''MY3 wheel'', the design of the MY3 wheel is introduced. In Section ''AGV with MY3 wheels'', the omnidirectional AGV with MY3 wheels is presented. In section ''Kinematic model'', the kinematic model of the AGV is derived. In Section ''Guiding method'', the guiding method of the AGV is established. In Section ''Experiments'', experiments are performed to verify the kinematic model and guiding method. Finally, some conclusions and future work are given in Section ''Conclusions and future work''.

MY3 wheel

Fig. 2 shows the basic structure of the MY3 wheel. The wheel consists of two balls with equal diameter on a common shaft. The two balls are both sliced into four spherical crowns, and each spherical crown can rotate freely around its own shaft. The two sets of spherical crowns are mounted at 45° from each other to produce a combined circular profile. When the common shaft is driven, the two sets of spherical crowns can make an alternate contact with the ground to realize a continuous active motion for the MY3 wheel, and the free rotation of the crown contacting with the ground can realize a passive motion for the MY3 wheel. A 15° gap is designed between two adjacent spherical crowns to make the MY3 wheel much more insensitive to dirt and fragments on the ground, and the precision of the circle profile which can be influenced by the gap has been checked by Ye et al. (2014). Moreover, because the four spherical crowns in one set can realize a mutual support with each other, the MY3 wheel has a good capability of load carrying compared to conventional omnidirectional wheels. In addition, the cover of the spherical crown of the MY3 wheel is made up by polyurethane (PU) but not aluminium alloy which is adopted by earlier MY wheels, and this modification is very useful for resisting the slippage between the wheel and the ground.

AGV with MY3 wheels

The prototype of the omnidirectional AGV with the MY3 wheel is shown in Fig. 3. The mechanical system of the AGV consists of a mobile platform and a three-layer carrier. On the mobile platform, four MY3 wheels are arranged evenly with a 90° interval angle to realize the omnidirectional motion, and some optical color sensors that can guide the AGV is also installed on the platform. As to the three-layer carrier, the bottom layer is used for carrying four DC motor modules (including the motor, motor driver, gearbox, and encoder) that actuate the four MY3 wheels respectively. The middle layer is used for carrying the controller and battery of the AGV. The top layer is used for carrying the material transported by the AGV, and a camera and a WIFI module are installed on the top of this layer. The specifications of the AGV are listed in Table 1, and some geometric parameters in the table are shown in Fig. 5.