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Design and Performance Evaluation of 4 Wheeled Omni Wheelchair with Reduced Slip and Vibration

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Abstract

Holonomic wheelchairs are being popular for their ability to move in constrained spaces due to their omnidirectional mobility. In this paper we have presented design and development of a 4 wheel driven omni wheelchair suited for indoor navigation with reduced wheel slippage and vibration. The design has been evaluated with wheel load measurement from current consumption and vibration measurement with a 3 axis accelerometer mounted on the chassis. From the result and analysis, it is evident that our proposed design shows less wheel slippage and vibration than existing designs. The system can find its application as an assistive aid for geriatric population or as a smart indoor mobility vehicle.

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Keywords: Omnidirectional whelchair; 3 axis joystick; Holonomic Control; Slip;

1. Introduction

Powered wheelchairs have been developed over the years for locomotion disabilities and for geriatric assistance. Smart electric wheelchairs are special class of powered wheelchairs, which are becoming a natural substitute of the conventional wheelchairs as an assitive device. Moreover, due to the ease of control, application specific human machine interface and smooth mobility, electric wheelchairs are becoming a popular indoor navigation vehicle. One of the first prototypes of smart wheelchair was proposed by Madarasz et.al[1] in 1986 which presented a wheelchair designed to transport a person to a desired room within an office building given only the destination room number. Since then, many such smart wheelchairs have been developed and few have been commercialized[2],[3]. Most of the developed smart wheelchairs are modification over existing commercially available powered wheelchairs with add on facility to enhance maneuverability, navigational intelligence and multi-modal control interfaces. To name a few, NavChair[4], Office wheelchair with high Maneuverability and Navigational Intelligence (OMNI)[5], Mobility Aid for elderly and disabled people (MAid)[6], Smart Power Assistance Module (SPAM)[7], TinMan[8], etc. provides controlled indoor navigation. Among the wheelchairs developed with omnidrive or omnidirectional mobility, the OMNI (Office

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Wheelchair for High Manoeuvrability and Navigational Intelligence for People with Severe Handicap) is a mecanum wheeled wheelchair developed for individuals with severe mental and physical disabilities. Another example of an omnidirectional wheelchair is iRW[9], which provides a telehealth system with easy-to-wear, non-invasive devices for real time vital sign monitoring and long-term health care management for the senior users, their family and caregivers.

In this paper we have presented design and development of a 4 wheel driven omni wheelchair with reduced wheel slippage and vibration. All the wheelchairs or indoor transporters with holonomic drive are developed with mecunum wheels or are a three wheeled omni platform. Mecunum wheels are inherently suitable for handling high load but its turn rate is slow compared to omni wheels. 4 wheel platform with omni wheels are difficult to design, mainly because of its unequal ground reaction force. If designed properly, 4 wheeled omni platform provides better performance than platform developed with mecunum wheels. We propose a unique wheelchair design with omni wheels and proper suspension mechanism to provide enhanced mobility in indoor environment. The design has been evaluated with wheel load measurement from current consumption and vibration measurement with a 3 axis accelerometer mounted on the chassis.

2. Methodology

2.1. Omnidirectional Wheelchair Platform Development

Omni directional wheelchairs[14,15,16] posses special maneuverability due to the omni wheels which allows translational as well as lateral mobility. Unlike differential or steering drive, omni drive systems does not possess holonomic constraints, allowing motion in both the body axis possible. Moreover, translational movement along any desired path can be combined with a rotation, so that the robot arrives to its destination at the correct angle[17], [18]. In order to achieve this, the wheel is built using smaller wheels attached along the periphery of the main wheel. Each wheel provides traction in the direction normal to the motor axis and parallel to the floor. The forces add up and provide a translational and a rotational motion for the robot.

Holonomic drive system is usually designed with mecanum wheels (4 wheeled configuration) and omni wheels (3 wheeled configuration). 4 wheeled omni driven wheelchair are not common, but if designed properly, 4 wheeled omni drive provides better traction force compared to mecanum while turning. Design of a 4 wheel driven Omni Wheel based platform needs special attention. Regardless the surface type, all four wheels should receive equal ground reaction force (GRF) or else there are chances of wheel slippage. A Omni wheelchair is designed to support 120 Kg including the platform's own weight and payload with proper suspension mechanism to provide equal GRF in all wheels.

Wheelchair design comprises designing of the motor wheel assembly, a suspension mechanism and a chasis with sufficient load bearing capacity. Fig.1 shows different parts of the omni wheelchair. Motor wheel assembly (Fig.1a) consists of a 'L' shaped part called 'Main L' which holds the dual omni wheels of 8 inch diameter and ball bearings. The upper side of the 'Main L' houses two slots for attachment of another smaller 'L' shaped mild steel part labeled as 'secondary L'. The 'secondary L' houses a pair of vertical slots which connects a motor attach plate. The motor (Buhler, 24V) is firmly affixed with the motor attach plate. The horizontal slot present in the 'Main L', vertical slot present in the 'secondary L' provides the ability to align the motor shaft co-axially with the wheel rotational axis. This minimizes jamming of the motor shaft due to misalignment or manufacturing defects. Finally, a flange is designed to couple the motor shaft to the dual omni wheels. This motor-wheel arrangement prevents the system weight to be transferred to the motor shaft as radial load. Four of such assemblies are connected to the platform chassis.

The next most important issue to consider is the suspension system to ensure equal ground reaction force on the four omni wheels. Suspension system has been designed using rear shock absorber. The hydraulic damping present in the shock absorber reduces the oscillation in the system. A pair of rear shock absorber is selected on the basis of required spring stiffness, travel length. Fig.1b shows the designed front motor-wheel assembly with suspension mechanism, attached with the chassis. The suspension mechanism is intentionally connected in the front motor-wheel assembly to maintain the symmetry. The chassis is designed with mild steel 'L' of 20 mm width and 3 mm thickness. Finite Element Analysis is done in SolidWorks to optimize the width of the material at the given load. The chassis measures 540 mm x 440 mm and is rectangular to accommodate the suspension mechanism in the front. In the suspension design, two 'U' shaped mild steel plates are used as 'Hold plates' and named as 'Upper Hold Plate' and