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Omnidirectional Assistive Wheelchair: Design and Control with Isometric Myoelectric Based Intention Classification

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Abstract

Smart electric wheelchairs are becoming a natural substitute of the conventional wheelchairs as an assitive device for geriatric population and patients suffering from mobility disorders. There is a demand for developing powered wheelchairs with intelligent control to suit wide range of application in the field of assistive technology. This paper deals with the development of a 4 wheeled omnidirectional wheelchair and its control using a myoelectric user intention interface. Developed system is driven by holonomic drive system, exploring greater maneuverability compared to conventional powered wheelchairs. Myoelectric signals from forearm muscles are processed to extract some features for seven different wheelchair motion namely forward, backward, left, right, clockwise and anticlockwise turn and stop. A neural network classifier classifies the user intention and maps the intention to wheelchair motion. The developed system finds its direct application in transporting people with locomotor disability, geriatric population as well as an indoor navigation vehicle.

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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,

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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 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.

Research on smart wheelchair control now a days mainly focuses on different types of user interfaces to control the wheelchair. Conventional control of smart electric wheelchairs are mainly based on joystick[10], but joystick control possess limitation for elderly and disabled people, lacking full dextrous control of their upper limb. The keyboard and mouse are often used as the HCI devices. However it needs much training for the disabled and the elderly who are not familiar with computer. Many advanced alternative controllers and human-machine interfaces (HMIs) have been proposed, which includes vision based techniques, voice recognition, hand gestures, head or chin control, biosignal based control like EMG, EOG or EEG control[11-15], etc. Inspite of different control modes being researched and developed, each alternative controller has its own disadvantages due to application specific restrictions like voice interface is affected by noise, vision based techniques are computation costly and slow. There are still no clear standard control mode which can be universally accepted and easy to implement like joystick control. Among bio-signals, EMG signals are considered better for control purpose and are used to control a variety of assistive devices, e.g. robot arms[16], hand prostheses[17], and electric wheelchairs[18,19]. EMG-based powered wheelchair control is a much researched topic[20-24] and has been shown to be effective as an alternative control mode, specially for rehabilitation aid.

In this paper, we present development of an omnidirectional wheelchair and formulate an intention based control to operate the wheelchair. 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.

Developed system has been controlled an user intention based control using users myoelectric signal extracted from four forearm muscles. User's intention to perform certain hand gesture like forward, backward, etc. are mapped with motion commands of the wheelchair. EMG signals are processed to extract some features for seven different wheelchair motion namely forward, backward, left, right, clockwise and anticlockwise turn and stop. A neural network classifier classifies the user intention and maps the intention to wheelchair motion.

Developed wheelchair has been tested by five users to validate the performance of the developed system. Effectiveness and accuracy of the control interfaces have been compared with standard joystick based control paradigm.

2. Methodology

2.1. Omnidirectional wheelchair Platform Development

Omni directional wheelchair 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[25,26,27]. 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.

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.

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