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Simulation and control of multipurpose wheelchair for disabled/elderly mobility

N M. Abdul Ghani[a,*] and M O. Tokhi[b]
[a]Faculty of Electrical and Electronics Engineering, Universiti Malaysia Pahang, Pekan, Malaysia
[b]Deparment of Automatic Control and Systems Engineering, The University of Sheffield, Sheffield, UK

Abstract. This paper presents investigations into the development of modelling and control strategies for a multipurpose wheelchair as mobile transporter for elderly and disabled people. The research is aimed at helping people with physical weakness/disabilities in their upper and lower extremities to move independently without human intervention. A novel reconfiguration which allows multi-task operations in the same wheelchair system with improved design is modelled in Visual Nastran 4D (VN4D) software. A modular fuzzy logic control mechanism with integrated phases is introduced for the overall operations and two-wheeled stabilization of the wheelchair. It is shown that the proposed modular fuzzy control approach is able to ensure system stability while performing multipurpose tasks such as manoeuvrability on flat surfaces, stairs climbing (ascending and descending), standing in the upright position on two wheels and transformation back to standard four wheels with up to 50% less initial torque in comparison to previous designs.

Keywords: Multipurpose wheelchair, stair climbing, sit-to-stand, stand-to-sit, modular fuzzy logic control

1. Introduction

The current worldwide trend in increased disabled and elderly population has challenged extensive designs and advancements in mobility transport as essential needs. This includes mobility devices such as wheelchairs, which vary in designs depending on their functionalities, from use in sports for Paralympics or other sportspersons to individual use for outdoor and indoor environments. It is vital to an individual who uses the wheelchair as the main self-mobility transport to move from one place to another independently. Currently, standard four-wheeled wheelchair designs have some limitations and cannot perform standard routine tasks, such as stair climbing, sit-to-stand and stand-to-sit operations.

A stair climbing wheelchair will allow the user to utilise the same assistive mobility equipment to manoeuvre on stairs as well as on flat surfaces. There will be no need for an elevator or an assistant to perform stair climbing, and this will allow the wheelchair user to exercise independence. A significant amount of work has been reported in the literature on the development and control of stair-climbing wheelchairs. These include crawler type [25,27,39,41,42], wheeled type [24,33,37] and legged type [29] wheelchairs.

The crawler type wheelchair works well on an uneven terrain and provides a high terrain adaptivity. The first commercial wheelchair models were based on a single-section track mechanism capable of climbing up and down staircases [39,42]. The design of the overall stair climber mechanism needed more refinements so as to reduce its total weight. Moreover, crawler mechanisms have some drawbacks when stepping on the edge of the first step; the entire track is forced to rotate during climbing down a staircase [27].

Nakajima proposed a step-up gait called RT-Mover [29], which comprised a four-wheel-type mobile robot for upward step like a legged robot with simple leg mechanism. The robot can move like a wheeled robot on normal terrain and transform to legged mechanism

*Corresponding author: N M. Abdul Ghani, Faculty of Electrical and Electronics Engineering, Universiti Malaysia Pahang, 26600 Pekan, Malaysia. Tel.: +60 609 4246087; Fax: +60 609 4246111; E-mail: normaniha@ump.edu.my.

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