Chapter 1

1 Introduction

1.1 Introduction and motivation

Mobility dominance has always been highly valued but is sometimes over sighted in case of people with disability and the elderly. The number of disabled persons across the world has kept on increasing. For example in Great Britain, there are a total of 11.2 million disabled persons, of whom 0.8 million are children, 5.2 million are working adults and the same goes to pension people according to 2010/2011 disability prevalence estimation data (Disability factsheet, 2011). This has caused high demand on some form of transport mechanism and thus wheelchairs continue to play a vital role. The wheelchair designs range from traditional to electric-powered types with their associated advantages and limitations. However, most of the manual wheelchair designs are not capable of performing multiple tasks within the same wheelchair system. Thus, there is a significant gap between the able bodied and paraplegic people in utilizing the facility especially in case of different operations with compact and simple mechanism for use in confined domestic environments. The main goal of this work revolves around provision of assistance with electric-powered wheelchairs (EPWs) to help disabled/elderly people with lower and upper extremity impairments so as to increase their functional mobility to perform multipurpose tasks independently. The wheelchair system allows manoeuvrability on flat surfaces, stairs climbing (ascending and descending), standing in the upright position on two wheels and transforming back to standard four wheels. Various mobility assistive techniques are highlighted in this thesis and recent advances in wheelchair mechanism are described.
1.2 Multi-functions wheelchair

EPWs allow functional mobility for people with spinal cord injury (SCI) and paraplegics with paralysis in both upper and lower limbs. It becomes increasingly prominent as more wheelchair users have changed to powered machine due to the ability to move within their homes and communities independently especially for people with high level of impairment. This chapter highlights current work for multipurpose wheelchair including stability control wheelchair, stair climbing wheelchair and sit-to-stand/ stand-to-sit manoeuvring using two wheeled wheelchair.

1.2.1 Stability control wheelchair

Three or more points of contact on the ground are needed for a wheelchair to be stable, similar to modern vehicles approach. If a balance mechanism is used, two points of contact will be adequate, e.g. a rickshaw supporting a person as an external balance mechanism, bicycle and motorcycle in case of using an internal balance mechanism. The person in this case needs to control the vehicle’s lateral motion in order to maintain the appropriate COG position for the bicycle and motorcycle. If a single point of contact with the ground is used, such as unicycle and wheelbarrow, then acquiring control and balance at both side to side and front to rear will be a complex task.

It is vital to ensure safety of a user during manoeuvring using a wheelchair to prevent any severe accidents such as tips and falls. Tipping stability occurs when one or more wheels of a wheelchair are lifted due to the loss of control of a driver. Cooper et al. (1998) indicated that leg rests play a significant role on the wheelchair stability and can increase the possibility of falling and tipping. Corfman et al. (2003) also suggested that proper leg rest position and the use of seatbelt might guarantee the stability of the wheelchair when traversing on any obstacles.

Torres et al. (2000) implemented a level sensor to detect the seat height and maintain level while the wheelchair traverse on untreated surfaces through
extension and retraction control mechanism. A commercialized iBOT wheelchair utilized the balance mode throughout the wheelchair operation which operates on two-wheeled mode using inverted pendulum principle. It controls the (COG) of the wheelchair system by bringing the rear wheels at the upright vertical position. It uses the on board sensors system; gyroscope and encoder to measure the tilt angle of the seat, angular velocity and base linear velocity to drive and balance the iBOT system through the motor voltage and current (Kamen et al., 2002). Cooper et al. (2006) conducted a study to report the various types of wheelchair activities at home and in the community. The tasks include performing eye-to-eye level discussion with people and reaching items at higher shelves at home and library.

Similar to iBOT design principle with the ability to transform from four wheeled to two wheeled mode with additional capabilities to lift the seat to a higher position has been introduced by Ahmad et al. (2011, 2014). They used the two-links inverted pendulum concept for lifting both the front wheels and stabilizing the overall wheelchair body on its rear wheels at the upright two wheeled position. However, the front wheels dimension, called caster wheels in this design were much smaller than the rear wheels which contribute to easy transformation processes. Moreover, the wheelchair produced initial high torque at the wheels and tilt motors (Link 1 and Link 2) to lift the overall mechanism to two-wheeled upright position. This will produce big tilt angle at the beginning of the transformation process as the overall system need to be tilted with such high power. The comfort issue of the user is important in this case especially for a disabled person and elderly.

1.2.2 Stair climbing wheelchair

Stair climbing wheelchair provides a facility to the user to utilize the same assistive mobility equipment to move on a flat surface and on the stairs. There is no reliance on the elevator or an assistance to perform stair climbing, thus leading to independent life. A number of stair-climbing wheelchair mechanisms have been developed and these include crawler type, leg type, hybrid type and wheeled type; as described below.