A Novel Stair-Climbing Mobile Platform and its Motion Control System

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Thesis submitted in partial fulfillment of the requirements for the degree
Master of Philosophy

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University of Moratuwa
Sri Lanka

January 2022

Declaration

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Abstract

Independent life is one of the most significant concerns for a disabled person specially when considering their mobility requirements. Due to the availability of facilities, both indoor and outdoor, wheelchair users face many difficulties when entering a building via staircases. Particularly, in the developing world, the concern about difficulties faced by the disabled and elderly community in accessing buildings is inadequate. As a result, most of the wheelchair users are forced to stay home and it makes their lives dependent. Since many years, scientists and researchers have been working for providing effective solutions for the mobility issues of disabled community. Stair-climbing wheelchair is one of the most powerful and popular solutions which is currently in use for mobility requirements of the disabled community. But most of the existing stair-climbing wheelchair designs have a drawback of the lack of adaptability especially at the top and the bottom of the staircase

As a solution, a novel stair-climbing mobile platform with improved stability and safety is presented in this thesis. In this research, the novel mobility platform has been designed referring to the standards of staircases which have been accepted worldwide. Based on those stipulated parameters, the maximum operating angle of this design is selected as forty degrees, which is the highest angle as per the standards. Based on the literature review, track based arrangement is used as the basic mechanism for the mobile platform design because of speed, grip and user comfort. By considering the main problem of the track mechanism, variable configuration of track mechanism is used for the design in order to achieve adaptable arrangement to the staircase. Also detail analysis of design safety based on different postures on staircases are discussed and basic conditions for stair-climbing operation are derived. By considering the prototype construction, a detailed description of development stages of prototype is explained based on practical approaches in order to minimize the defects in the final product.

In order to validate the stable and safe operation, simulation and experimental studies have been carried out. According to proposed novel motion plans for stair-climbing operation, the simulation study illustrates that there does not exist any sudden disturbances on the user's operating path over staircase. By following the same procedure as used in simulation study, experimental studies have been carried out by implementing motion plans for each stage of operation. Based on the results, it confirms that the operating path of the design follows a similar behaviour as discussed in the simulation study. For further justification of the safety of the design, the actual operating path is well observed by using a video tracker software. Based on the actual operating path of the design, it confirms that throughout the staircase, the design maintains a stable operating path without creating any sudden disturbances on the mobile platform. Thus, it confirms that this design can provide a comfortable operation for the user whilst maintaining stable and safe posture throughout the operation.

Index terms— stair-climbing, mobile platform, wheelchair, track mechanism

Acknowledgement

I would like to express my sincere gratitude for my parents, my family members, relatives and friends for providing me financial support to make this research a success. Their guidance and support offered to me throughout this difficult and tough time period is greatly appreciated because if not for their support and encouragement I would not have been able to complete this research and prototype development successfully due to my disabled condition.

I wish to express my humble gratitude to main supervisor, Prof.Rohan Munasinghe, Department of Electronic and Telecommunication Engineering, University of Moratuwa, for giving me this wonderful opportunity to carryout this research under his supervision and also I would like to thank him for his valuable advice, continuous guidance and the tremendous support given in order to make this research a reality. Also I would like to extend my gratitude towards my co-supervisor, Dr. Thilina Lalitharatne, Department of Mechanical Engineering, University of Moratuwa, for his academic advice, support and encouragement in completing this research work. I would like to express my gratitude to the review panel members of this research who have guided me throughout the last few years.

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List of Abbreviations

Abbreviation	Description
a	Going
b	Rise
c	Hypotenuse
θ	Angle of staircase
l_f	Length of front arm
l_m	Length of middle arm
l_r	Length of rear arm
l_c	Half length of contacting points of chassis
h_c	Minimum stair edge clearance height of chassis
$h_c^{'}$	Marginal value for minimum stair edge clearance height
$\theta^{'}$	Angle of margin
r	Radius of arm
M_{fg}	Weight of front arm
M_{mg}	Weight of middle arm
M_{rg}	Weight of rear arm
M_{bg}	Weight of body
T_f	Tractive force of front arm
T_m	Tractive force of middle arm
T_r	Tractive force of rear arm
T_{ft}	Total tractive force acting on front arm
T_{mt}	Total tractive force acting on middle arm
T_{rt}	Total tractive force acting on rear arm
τ_t	Required minimum torque
τ_m	Torque of driving motor
N_f	Normal reaction force on front arm
N_m	Normal reaction force on middle arm
N_r	Normal reaction force on rear arm

l_b	Distance to CM of body from front joint
θ_b	Angle of CM of body
l_1	Distance to step from rear joint
θ_s	Incline of chassis
l_2	Distance to step from front joint
M_{tg}	Total weight of design including user
λ	Stable marginal angle
d	Distance to stable marginal angle
l_t	Distance to CM of design from stair edge
μ	Friction coefficient
x	Height of user's placement
ω	Orientation of user's position
α	Angle of front arm
β	Angle of middle arm
γ	Angle of rear arm
F_{res}	Total resistance force
P_{flat}	Power consumption in flat surface
P_{stair}	Power consumption in stair-climbing
P_{max}	Required maximum power
V_{flat}	Speed in flat surface
V_{stair}	Speed in staircase
η	Coefficient of power transmission
K_s	Safety factor
τ_{stair}	Required torque in stair-climbing
ω_s	Angular velocity of wheel
x_{f1}, x_{f2}, x_{f3}	Parameters of front arm geometry
x_{m1}, x_{m2}, x_{m3}	Parameters of middle arm geometry
x_{r1}, x_{r2}, x_{r3}	Parameters of rear arm geometry
α_1	Angle between front linear actuator and front arm
α_c	Angle between front arm and chassis
l_{f1}	Distance to contact point from front joint
F_{fl}	Front linear actuator force
α_{con}	Fixed angle of front arm
β_{con}	Fixed angle of middle arm
γ_{con}	Fixed angle of rear arm