Investigation of Effect of Human Robot Interaction with Lower Limb Exoskeletons

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DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Abstract

Continuous development of exoskeletons (wearable robots) is essential to enhance the user experiences and performances of the wearable device. Therefore, it is necessary to determine human ergonomics and the comfort levels of wearable robots. These aspects can be analyzed by determining human-robot interaction (HRI). HRI is classified in cognitive- HRI (cHRI) and physical-HRI (pHRI) in the literature. cHRI involves the identification of complex human expression and physiological aspects. These pieces of information can be observed using a human-robot cognitive interface. Electroencephalogram (EEG) and electromyography (EMG) are mainly used sensing methods in cHRI. EEG is used to identify electrical activities of brain, while EMG is used to identify electrical activities of muscles. Furthermore, pHRI involves evaluating physical quantities such as position, force, and pressure between humans and robots. In order to identify pHRI with wearable robotic interfaces, a novel surface muscle pressure (SMP) sensory system was developed. The SMP sensor was calibrated and evaluated using surface electromyography (sEMG) data for two separates experimental scenarios. Hence the system was proposed to determine the pHRI of wearable robotics.

In order to determine HRI, a dummy lower limb exoskeleton was designed and manufactured in compliance with human ergonomics and biomechanics. The exoskeleton consists of 8 degrees of freedom (DoF) motions with variable limbs and weight attachment locations. Furthermore, sEMG, motion analysis, and SMP sensory systems were used to carry out the experiments. Moreover, a human lower limb model simulation with ground force reaction prediction was developed to determine the inverse dynamics. The experiments were carried out without exoskeleton, with the exoskeleton, and with exoskeleton weight attachments with six healthy subjects for the walking motion. A qualitative, comfortable level analysis was carried out simultaneously for each experiment. Captured SMP, sEMG, inverse dynamics and qualitative results were processed and feature extracted to evaluate HRI for different weight distributions and attachment locations. The relationship between exoskeleton attachments and locations was observed. The experiment results have provided an improved understanding of HRI for developing practical and ergonomically comfortable lower limb exoskeleton devices.

***Keywords*-Lower-limb Exoskeletons, Human-Robot Interaction, Electromyography, Inverse Dynamics**

DEDICATION

To my parents,

Chandra Chandrasiri and Sudharma Chandrasiri

Thanks for your great support and

continuous care.

Without you none of my success would be possible.

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LIST OF ABBREVIATIONS

cHRI	Cognitive Human Robot Interaction
DAQ	Data Acquisition
DC	Direct Current
DH	Denavit Hartenberg
DLS	Damped Least Squares
DoF	Degrees of Freedom
EEG	Electroencephalography
EMG	Electromyography
FSR	Force Sensitive Resisters
HRI	Human Robot Interaction
HK	Hip Knee
HKAF	Hip Knee Ankle Foot
KAF	Knee Ankle Foot
pHRI	Physical Human Robot Interaction
SMP	Surface Muscle Pressure
THKF	Trunk Hip Knee Foot
THK	Trunk Hip Knee