

論文 / 著書情報  
 Article / Book Information

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Title(English)	DEVELOPMENT AND EVALUATION OF A GAIT-ASSIST WEARABLE ROBOT USING INTERACTIVE RHYTHMIC STIMULATION TO THE UPPER AND LOWER LIMBS
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## 論文審査の要旨及び審査員

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論文審査の要旨 (2000 字程度)

The title of this thesis is “Development and evaluation of a gait-assist wearable exoskeleton using interactive rhythmic stimulation to the upper and lower limbs”. This thesis presents an exploration of the effect of interactive rhythmic stimulation to the upper and lower limbs from the perspective of mutual entrainment in human-robot interaction, and upper-lower-limbs’ coordination in human locomotion. It comprises of five chapters.

In Chapter 1: Introduction, the author summarized the recent development of the power-assist wearable exoskeletons to the lower limbs and pointed out that all the previous exoskeletons focused on a master-slave control principle, whereby the robot (i.e., master) controls the human (i.e., slave)’s gait to a target trajectory. In addition, these previous exoskeletons focused on a direct power-assist support to the wearer’s lower limbs without considering upper-lower-limbs’ coordination. Therefore, the author asserted the necessity for the development of a gait-assist wearable exoskeleton (i.e., WalkMate) that provides interactive rhythmic stimulation to the upper and lower limbs based on the mutual entrainment principle in human-robot interaction, and upper-lower-limbs’ coordination.

In Chapter 2: Gait-assist wearable exoskeleton to the upper and lower limbs: The author presented the development and evaluation of a gait-assist wearable exoskeleton using interactive rhythmic stimulation to the upper and lower limbs, aiming to evaluate the remaining problems associated with the exoskeleton for the healthy elderly’s gait. The author found that stimulation to the upper and lower limbs significantly increases the shoulder- and hip-joint amplitude without adversely affecting the elderly’s upper-lower-limbs’ coordination. However, the author also found a significant increase in the coefficient of variance, *CV* of the shoulder- and hip-joint amplitude for an elderly subject, which indicated gait instability for the elderly. The author speculated that this increase in gait variability might be attributed to the heavy weight of the lower limb motors, and a direct stimulation to the wearer’s lower limbs. Hence, the author proposed the development of a gait-assist wearable exoskeleton using interactive rhythmic stimulation to the upper limbs to overcome the aforementioned limitations.

In Chapter 3: Gait-assist wearable exoskeleton to the upper limbs: The author presented the development and evaluation of a gait-assist wearable exoskeleton using interactive rhythmic stimulation to the upper limbs. The author found that stimulation to the upper limbs statistically significantly increases the hip-swing amplitude for the upper-limb-assist condition at all lag times, and statistically significantly decreases the hip-swing period at the 40% lag time condition. Further, this stimulation does not adversely affect the *CV* of the hip-swing amplitude and period, and upper-lower-limbs' coordination for the elderly's gait. Hence, the author asserted that interactive rhythmic stimulation to the upper limbs could provide gait-assist support for the elderly with gait stability.

In Chapter 4: General Discussion, the author asserted that the gait-assist wearable exoskeleton that provides interactive rhythmic stimulation to the upper limbs is a significant improvement over stimulation to the upper and lower limbs. First, although no stimulations were provided to the lower limbs, stimulation to the upper limbs statistically significantly increases the hip-swing amplitude and gait speed for the elderly's gait, which indicated the presence of an upper-lower-limbs' neural coupling. Second, although no stimulations were provided to the lower limbs, stimulation to the upper limbs showed a symmetrical pattern in the upper-lower-limbs' coordination, which indicated upper-lower-limbs' coordination for the elderly's gait. Third, stimulation to the upper limbs does not statistically significantly increase the *CV* of the hip-swing amplitude and period, which indicated gait stability for the elderly.

In Chapter 5: Conclusion, the author summarized that interactive rhythmic stimulation to the upper limbs has a positive effect for the elderly's gait as manifested through a statistically significant increase in the hip-swing amplitude and gait speed without adversely affecting their upper-lower-limbs' coordination and gait stability. Hence, the author concluded that stimulation to the upper limbs at an optimal condition could provide a promising neurorehabilitation strategy for the elderly's gait.

In summary, this thesis addressed the importance of interactive rhythmic stimulation to the upper limbs and provides evidence that this stimulation has a positive effect for the elderly's gait. Therefore, we agree that this thesis meets the criteria to complete the degree of Doctor of Engineering.

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