論文の要旨

題 目　Adaptive Assist Control Based on Impedance Model of Pneumatic Gel Muscle and Its Application in Augmented Walking Suit (空気圧ゲル人工筋のインピーダンスモデルに基づく適応支援制御と拡張歩行スーツにおけるその応用)

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One's ability to perform daily routine tasks independently is linked with a healthy lifestyle and a good quality of life. The quality of life affects due to lack of ability to carry out daily tasks. These situations could be injuries, accidents, weak muscles or aging. Technologies such as exoskeletons or exosuits or wearables assistive suits are developed to address such situations. While each one trying to reduce musculoskeletal stress from doing heavy-duty tasks of rigorous activities, they individually add unique value to the result. Exoskeleton aims to restore movements of disabled or amputees or provide a superhuman capability for its users. Exosuit aims to improve wearability of the device by minimizing the metallic structure as observed in the exoskeletons. These devices aim to help in the rehabilitation process, reduce energy expenditure for task addressed explicitly by such devices. Exoskeletons can augment human capability significantly by transferring all the load to ground, but it is challenging to use exoskeletons in an uncontrolled environment, taking on and off is also a challenge. Exosuits, on the other hand, addressed wearability and reduce muscle activation but still use electric actuators, which restrict its use only for the specific task in the controlled environment. The use of such technologies for farmers, elderly support is not wildly discussed. There is a gap in requirement where human augmentation device is needed, which is wearable, and lightweight to reduce muscle effort for desired tasks. In our study, we considered these factors are more critical for human augmentation. We aim to design and developed a wearable assistive suit to reduce human muscle activation using biologically inspired soft actuators, i.e., pneumatic artificial muscles (PAM), to mimic the human muscle activation for walking gait. In our study we proposed using soft actuators to developed compliant and adaptive assist control to develop the lightweight walking augmentation device. The outline of the study is as follows.

In chapter 1, we discuss background study and define a soft wearable assistive suit. In this literature survey we will discuss various factors affecting human augmentation devices, challenges and our motivation to address these in our study. Actuators, devices, control algorithms, practical application are some of the factors considered and used for comparison.

In chapter 2, we discuss the design and development of an augmented walking suit. Augmenting or assisting human motion requires understanding of motion and motion planning. A detailed gait cycle classification and contralateral foot orientation-based model is explained to identify individual gait phases. We used pneumatic Gel Muscle for

actuator in AWS. We developed impedance model of PGM by experimenting and measuring impedance characteristics. Based on these, we assist control strategies are developed and implemented using gait phase detection algorithm.

In chapter 3, we discuss the evaluation methods of the augmented walking suit. The effectiveness of AWS was studied using biomechanical simulation. Changes in muscle force and kinematics during one gait cycle are measured and evaluated. A customized simulation of PGM model is developed for this study. Physiological evaluation experiment was conducted where subjects wore the AWS and conducted walking experiments with different assistive force and control algorithms. Subjects were selected randomly and could rest or stop the experiment if they wish to. The effect of AWS on muscle activation was studied by conducting statistical analysis on normalized average sEMG data.

In chapter 4, we discuss the plot trials conducted to study the adoption of AWS in rural areas for elderly and small and independent farmers or workers. This project was conducted in collaboration with PhD students in other graduate schools at Hiroshima University. We studied how social and cultural aspects affect adoption of wearable assist suits. The pilot trial was focused on elderly and independent farmers.

In chapter 5, we discuss the summary of the study and future scope.