Research Proposal

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1 Introduction

The application of exoskeleton has become an emerging field in recent years, due to its performance in assisting locomotion for people with disabilities [1]. While conventional exoskeletons incorporate integrated mechanical systems to enhance the performance of mechatronics control, they lack necessary design space for adjustments, thus failing to accommodate individual needs. As a result, most amputees still suffer from locomotor defects, thus significantly modify the biomechanics and muscle activity of joints [2]. Therefore, **personalization** of exoskeletons design becomes an emphasis of the field, which aims to personalize the experience in the correction of locomotion defects [3], and reduce the energy cost for long-distance locomotion [4] for different individuals.

2 Research Questions

Recent studies have chosen two major types for personalizing the design of exoskeletons: unpowered exoskeleton [5] and powered exoskeleton [6]. However, trade-offs exist in both designs, which fails to provide wider design space for personalization. While unpowered exoskeleton relieves the added mass penalty in exchange of a less power-density provided by actuation, powered exoskeleton is able to provide a larger power density but restricted by the added weight from mechatronics parts [7]. Such trade-offs make it difficult to generalize the design for exoskeleton devices, which also adds difficulty to personalize the experience [8].

In essence, The ultimate goal of exoskeleton design is to be generalized in design and personalized in user experience. A balance should be made between the benefits and drawbacks of different exoskeleton design, and generalize the design for personalized exoskeleton devices.

Therefore, the key research objective is put forward as follows: **find the optimal design to balance the benefits and drawbacks of different exoskeleton design, and generalize the design for personalized exoskeleton devices.**

3 Plans and Methods

The solution of the personalization design is two-folded. Firstly, **the biomechanics of the user should be well understood, by evaluating the metabolic cost more precisely**. Such precise evaluation of metabolic cost can be performed by **sensor fusion**, which combines information from various sensors, such as respirometry and electromyography (EMG) sensors [1]. As a result, such evaluation provides a better understanding of the mechanics of human locomotion, thus contributing to a more detailed classification of locomotion modes and walking speeds in different situations. Such analysis on the biomechanics of human locomotion leads to a mixed strategy for control [9], which combines data-driven and classical control methods. The development of such a mixed control strategy should provide a more adaptable and dynamic movement for the user, thus reducing the energy cost of locomotion.

Secondly, **the operation workflow of the exoskeleton design should be optimized for generalizing personalized exoskeleton devices.** On the one hand, variable impedance should be applied to the low-level controller to provide adjustable parameters, thus reducing the metabolic cost of locomotion [1]. On the other hand, the components of the mechatronics system should be adjustable [10] [11], while maintaining control bandwidth [12]. Such design should aim to provide net energy gain for the user [6], thus personalizing user experience in the correction of locomotion defects and reducing the energy cost for long-distance locomotion.

4 Significance

Overall, the research on the personalization of exoskeleton design is significant in various aspects. On the one hand, the research provides a more detailed understanding of the biomechanics of human locomotion, thus contributing to a more detailed classification of locomotion modes and walking speeds in different situations. On the other hand, the research unveils a generalized method for personalizing exoskeleton devices, while maintaining the function of reducing energy cost [4], and correcting gait patterns [3]. Therefore, the research provides a feasible plan to balance the benefits and drawbacks of different exoskeleton design, and generalize the design for personalized exoskeleton devices.

References

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