# 論文 / 著書情報
# Article / Book Information

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| 題目(和文) | 安全性と快適性を改善した手首・前腕のリハビリテーションのための装着型ロボットの運動力学解析および設計 |
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# 論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）


This dissertation focuses on kineto-static analysis and design of a wearable hybrid robot for wrist and forearm rehabilitation. The design requirements of the proposed robot are not only to achieve the required rehabilitation functions, but also to improve the safety and comfort of users. To achieve this goal, a design methodology is proposed with the consideration of human-robot interface behaviors and integrated the connection parts into the overall design of the rehabilitation robot. The proposed wearable hybrid robot is developed based on the design methodology and an experimental study is conducted to evaluate its performance and comfortability.

By applying the proposed design approach, firstly, starting from a simple planar 1-DOF wrist rehabilitation robot, kineto-static analysis of the robot is conducted. The effects of the initial offset and the use of compliant components are investigated. From the results of the analysis, the initial offsets along the lateral direction increase the force applied to the human body, so special attention should be paid to reducing it. With the offsets less than the proposed value, the safety of the user can be ensured when using the wearable rehabilitation robot. In addition, the use of compliant elements with less stiffness can reduce the unwanted force by 38% compared to the case without compliance. Furthermore, the effect of the addition of passive joints to the exoskeleton is investigated. From the analysis results, the soft part of the human being is regarded as a passive joint with the ability to compensate for joint misalignment and the compact design of the robot with improved comfort and safety is proposed. Moreover, the deformations of human soft tissues with nonlinear stiffness behavior and deformations in 2 translations and 1 rotation are addressed. Through the simulation results, the range of motion of the robot may reduce due to the effect of human tissues and it should not be ignored in the design.

Next, the lower-mobility parallel robot which has less than 6-DOFs, has a simpler structure with reduced cost and weight for in-home rehabilitation. Therefore, in order to support wrist rehabilitation movements, the 3-RPS parallel robot is designed as a wrist rehabilitation robot. The parasitic motions of the 3-RPS are analyzed and the effects of parasitic motion and initial offsets are investigated. Through the analysis results and with consideration of safety and comfort of the users, an optimization for the design of the 3-RPS parallel rehabilitation robot is performed. The proposed design has reduced applied forces/torques applied to the human limb, which can improve the safety and comfort of the user.

Finally, a wearable parallel-serial hybrid robot for wrist and forearm rehabilitation is proposed. The robot can perform the FE and RUD movements of the wrist and the PS movement of the forearm. For the FE and RUD movement, the 3-RPS is proposed with the consideration of reducing applied forces/torques to the human limb. Furthermore, based on the investigation of misalignment compensation, the novel RRPP and RRRR mechanisms are applied for joint misalignment compensation to improve the comfort and safety of the user. By applying the proposed design methodology, the robot has improved safety and comfort. In addition, it is lightweight and portable due to most of the parts are manufactured by 3D printing in onyx material reinforced with carbon fiber, therefore the robot is suitable for in-home rehabilitation. Moreover, an experimental study to evaluate the robot' s performance by using motion capture system and assess comfortability by questionnaires. The results of the experimental study show that the proposed design methodology is effectiveness for designing and the usability of the proposed robot is acceptable. However, some modifications of proposed robot are needed to improve the ROM and comfort of the use. In addition, based on the feedback of the subjects, the improved version of the design is proposed to solve some problems reflected by the subjects. Furthermore, the TI of the modified design is evaluated, and

it shows that the performance of the modified design is improved. With the features of lightweight, portable and safer design, the proposed wearable robot is expected to be suitable for in-home rehabilitation.

The contribution of this thesis is the development of a wearable rehabilitation robot for wrist and forearm with consideration the safety and comfort. In addition, a design methodology is established which integrates the connection parts between the human and the robot into the overall design of the rehabilitation robot considering human-robot interface behaviors. This methodology can not only apply to the cases described in this dissertation, but also can be applied to other wearable rehabilitation robots. By applying the proposed design methodology, a wearable rehabilitation robot for wrist and forearm rehabilitation with improved safety and comfort is proposed and its performance is evaluated with an experimental study.