論文 / 著書情報
Article / Book Information

題目(和文)	親指のリハビリテーションのための装着型過拘束パラレルロボットの開発
Title(English)	Development of Overconstrained Wearable Parallel Robot for Thumb Rehabilitation Therapy
著者(和文)	崔 佑赫
Author(English)	Woohyeok Choi
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 系 機械 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 工学 ）
学生氏名： Student's Name	Choi Woohyeok	指導教員（主）： Academic Supervisor(main)	武田行生
		指導教員（副）： Academic Supervisor(sub)	菅原雄介

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

The rehabilitation robot is the robot that aims to recover the human motor function through assisting or reinforced the motion of human movement. This robot is expected to one of the solutions to the lack of therapist. One of the distal parts of the human body, the thumb, is related to the dexterity skill, and it supports other fingers. Because the thumb's damage prevents the dexterity skill and makes the patient uncomfortable, thumb rehabilitation is essential. As the thumb carpometacarpal (CMC) joint structure is very complex, it is hard to allow its mobility to control by the mechanical joint. The misalignment issue, which is the mismatched phenomenon between the robot's axis and the finger joint axis, is the exoskeleton type's challenge point. In previous research, the exoskeleton type designs are proposed to allow the finger joint by the mechanism, but those designs are not for the CMC joint. Moreover, most of those are designed their thumb part to focus on controlling the CMC joint's partial movement. On the other hand, the previous research's end-effector type design is not necessary to design with consideration allowing the rotational mobility between finger and mechanism.

Based on these backgrounds, the (2-RRU)-URR parallel mechanism, which combined each advantage of two design types, is proposed in this thesis. The proposed mechanism is designed to attach its base part to the palm and surface and the output link is attached to the center of the thumb. This mechanism has characteristics such as lower mobility, an overconstrained mechanism, and the providing compound motion that consists of rotational and translational motions. To consider designing for thumb rehabilitation, it should know the characteristics of the mechanism before designing the proposed mechanism through the kinematic analysis. Moreover, since the proposed mechanism being designed for thumb rehabilitation therapy, considerations such as the mechanical part's placement in hand and the anatomical or the kinesiological information are necessary to design the mechanism.

In this thesis, a parallel mechanism was proposed for thumb rehabilitation therapy. The basic kinematics of the proposed mechanism, such as displacement analysis, velocity analysis, static analysis, and workspace analysis, were carried out. Furthermore, the geometric design with the human hand and the user test with the prototype were described. This thesis is consisting of six chapters.

In chapter 1 “Introduction”, the background of this research, the related previous research, the objective of the research, and the thesis composition were introduced.

In chapter 2 “(2-RRU)-URR parallel mechanism”, the structure of the proposed mechanism was explained, and the kinematic analysis such as the mobility of the mechanism, displacement, and velocity were carried out. Through Grubler's formula and the inspection of the constraint condition through the screw theory, the mobility analysis results revealed that the proposed mechanism is overconstrained mechanism, and its mobility is three DOF, which consist of two rotational and one translational mobility. To understand the position relationship between the input and the output, the displacement analysis was considered by dividing it into two parts, respecting the structure of the proposed mechanism, and its calculation process of each part was derived. Combining each result of the calculations, the whole displacement analysis was derived. Besides, the overall Jacobian matrix, which indicates the constraint and the output velocity, was derived. Those analysis processes are proof through numerical examples.

In chapter 3 “Static analysis”, the method of the static analysis and its verification experiment were described. The method of the static analysis is using the overall Jacobian for deriving the required actuation torque when the external loads are given. To confirm this method, the simulation result and the experimental result with the experimental apparatus were compared. From the comparing result, it is confirmed that this method can be used to derive the required actuation torque of the proposed mechanism.

In chapter 4 “Workspace analysis and dimensional synthesis”, the definition of the effective workspace and its application for dimensional synthesis were described. The effective workspace, which has the required input torques to satisfy the safety requirement by the proposed mechanism's geometrical condition, is defined from the reachable workspace. The dimensional synthesis method finds the suitable condition that has a broad coverage of the effective workspace in the required workspace and a small link length from the design candidates. Based on this method, the numerical example is calculated for the sake to understand.

In chapter 5 “Prototyping and experiment with users”, the prototype design procedure for thumb rehabilitation with consideration of the thumb measurement data and its user test was described. The thumb measurement data is used for determining the required workspace and the input trajectory of the prototype. To consider the hand's attachment, the placement of actuators and their effects on the workspace are examined. Based on the preliminary works, the prototype for thumb rehabilitation was manufactured. The purpose of the user experiment is to confirm the possibility of the prototype controlling the rehabilitation movements. As the result of the user test, the prototype shows the performance to generate the required movement and the adaptation to fit on any hand size even though the limitation of the lack of the actuator torque exists.

In chapter 6 ``Conclusion and discussion'', discussing this thesis's whole achievements, the remaining points, the conclusion, and future works are described.