論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Design and Control of Single and Parallel Soft Pneumatic Helical Deformation Actuators
著者(和文)	YUANPeizheng
Author(English)	Peizheng Yuan
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12536号, 授与年月日:2023年9月22日, 学位の種別:課程博士, 審査員:塚越 秀行,三平 満司,倉林 大輔,鈴森 康一,髙山 俊男
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12536号, Conferred date:2023/9/22, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	システム制御　系 システム制御　コース	申請学位（専攻分野）： Academic Degree Requested	博士　（ Philosophy Doctor of ）
学生氏名： Student's Name	YUAN Peizheng	審査員主査： Chief Examiner	塚越秀行　教授

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

This dissertation discusses the design and control method of a single actuator and a double parallel actuator that generate helical-like deformation by pneumatic pressure, aiming to generate various curing and twisting with large deformations from a cord-like flexible body. First, I introduced the concept of “Helical Coupled Drive” as a method to generate various deformations with a small number of chambers. Next, I proposed a configuration and design method for a pneumatic actuator that generates a helical shape from the initial state of a flexible straight line. Furthermore, I introduced structures with two parallel placement and variable structural functions to generate various curving and twisting shapes including six representative shapes. In addition, I also proposed direct kinematics and inverse kinematics solutions, and demonstrated a control method to make the tip follow the target position. This paper consists of the following six chapters.

Chapter 1 "Introduction" described the background, significance, purpose and structure of this research. Pneumatic soft actuators have shape adaptability and affinity with the human body, and they are very promising. However, if we tried to realize a various curving and twisting shape with the conventional design method, it would lead to an increase in the number of chambers, and then to reduce the working space. Based on the above, the purpose of this paper was set to solve the above problems by introducing “Helical Coupled Drive” and to verify the effectiveness of its design and control.

Chapter 2 "SHA: Single Helical Actuator" proposed a single pneumatic soft actuator (SHA) that transforms from a cord shape to a normal spiral as a basic element that constitutes

a spiral interference drive, and described its design, manufacturing method, and operating characteristics. is clarified. First, the structure consisting of flexible rubber, anisotropically stretchable fabric, and non-stretchable wire was presented, and its fabrication method was shown. I also confirmed that a prototype SHA with an inner diameter of 11.6 mm could generate a maximum contraction rate of 78% and a traction force of 23 N when air pressure of 0.3 MPa is applied, and the validity of the constructed dynamic model.

In Chapter 3 "DHA: Double Helical Actuator", two types of design methods were proposed in which two SHAs are arranged in parallel to interfere with each other and a variable structure function is added to realize helical interference drive. First of all, DHA-I, which was a helical phase variable structure, could generate curves including shapes such as C-shaped curves, ordinary spirals, and non-uniform spirals with 4 inputs. Next, DHA-II, which was a helical phase/pitch/length variable structure, could generate various curves including 6 types of representative shapes such as J-shaped and S-shaped curves. After confirming through experiments that it was possible to grasp and pour a PET bottle at the same time by utilizing the above-mentioned shape transition process, the necessity of controlling the actuator to further evolve DHA-II was cleared.

Chapter 4 "Direct kinematics and Inverse Kinematics of DHA-II" discussed direct kinematics and inverse kinematics for controlling the curve shape of DHA-II. First, as direct kinematics, I focused on the motion of multiple discrete points provided along the central axis of the ligament, and by successively adding vectors indicating the direction of curvature and curvature in the cross section of each point, DHA-II It showed that the curve shape and orientation of is computable. In addition, as inverse kinematics, I focused on the six parameters that determine the shape and direction of the curve derived under structural constraints, and found that these could theoretically be controlled by the six input parameters of DHA-II. On the other hand, to simplify the measurement of the curve shape, I also proposed a simple inverse kinematics that obtains four input parameters under the condition

of constant length from the coordinates of the upper two points and the lower two points of DHA-II. The usefulness of this method was demonstrated by comparing the experimental results of the prototype and the prototype.

In Chapter 5, "Control System of DHA-II", a method for controlling the curve shape and direction of DHA-II was presented to verify the validity of the inverse kinematics proposed in the previous chapter. It was shown that the shape and direction of the target curving shape and orientation could be automatically followed by the target signals, combing with the position information of four points measured by the depth camera and the data calculated by inverse kinematics. As a result, the effectiveness of the control method proposed in this study was verified.

Chapter 6 "Conclusion" summarized the findings obtained in each chapter and described remaining issues and future prospects.