

論文 / 著書情報  
Article / Book Information

題目(和文)	
Title(English)	Mechanism and Control of Pneumatic Semi-universal Hand with Two Fingers Aimed for a Wide Range of Grasping
著者(和文)	Ashlih Dameitry
Author(English)	Ashlih Dameitry
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10782号, 授与年月日:2018年3月26日, 学位の種別:課程博士, 審査員:塚越 秀行,奥富 正敏,山浦 弘,中島 求,倉林 大輔
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10782号, Conferred date:2018/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

## **Dissertation Outline**

# **MECHANISM AND CONTROL OF PNEUMATIC SEMI-UNIVERSAL HAND WITH TWO FINGERS AIMED FOR A WIDE RANGE OF GRASPING**

**By:**

**Ashlih Dameitry**

**Advisor:**

**Hideyuki Tsukagoshi, Assoc. Prof.**

**Department of Mechanical and Control Engineering**

**Graduate School of Science and Engineering**

**Tokyo Institute of Technology**

**February, 2018**

## **ABSTRACT**

This research presents the mechanism design of a new lightweight pneumatic robotics hand with two fingers configuration, an intuitive control strategy with a novel sensing structure, and the new validation method to evaluate the versatility of the grasping. Taking inspiration from human two fingers dexterity, a new grasping taxonomy by index finger and thumb with semi-adduction criterion is introduced. Based on it, a novel two fingers actuator composed of six “V-open drive” joints is proposed, which is made by a pleated flat-tube and notched polyurethane-foam, and the performance for each 1-DOF, 3-DOF, and 5-DOF driving motion is compared. The data glove with “V-open sense” structure is also proposed to increase the sensing sensitivity of the human fingers motion. The performance of the system is discussed after comparing with the previously developed robotics hands.

## 6 CONCLUSION

### 6.1 Summary

In this research, the mechanism and control of lightweight pneumatic sensorless robotics hand with two fingers structure had been presented and the grasping versatility had been evaluated. The large force by weight ratio profile made the proposed fingers suitable for aerial manipulator application such as door opening and perching mission. The versatility was verified by teleoperation task and the proposed fingers capable of grasping a wide range of objects using various human-like grasping postures. The performances and specifications were also discussed by comparing with the previously developed robotics hand. Each point of the obtained results are described as follows.

Firstly, the background of the current research on robotics hand and its vast application had been reported. Recent research related to universal hand, mechanical hand, and semi-universal hand was explained and the merit and demerit were discussed. The research purpose and the potential contribution to the robotics hand application including aerial manipulator field by proposing a novel structure of pneumatic semi-universal hand with two fingers structure had been clarified.

The new lightweight underactuated pneumatic sensorless two fingers with 1-DOF motion were then proposed. The fabricated fingers consist of index finger and thumb mimicking human real fingers length. The joint is actuated by the new “V-open drive” mechanism which composed of polyurethane foam with notch and pleated flat tube actuator performing active flexion motion and passive extension. In order to grasp the various shape of objects, the torque distribution was designed to follow a uniformly distributed grasping force characteristics. The experimentation had been conducted to verify the capability of grasping various objects including the round-type doorknob.

The definition of the versatility, in which the capability to grasp a wide range of objects and postures for the two fingers robotics hand which was lacked in the on-going research field had been proposed. By studying the ability of human two fingers which is capable on grasping a wide range of objects, a new two fingers taxonomy by index finger and thumb had been introduced

which consist of 12 grasping postures and additional thumb semi-adduction criterion. The relationship between human fingers muscle and joint had been described, the significant contribution for each joint had been analyzed, and then the new underactuated 3-DOF semi-universal hand in which optimizing between lightweight structure and versatility and 5-DOF fingers in which maximizing the grasping versatility had been implemented. The proposed underactuated 3-DOF fingers was introducing the symmetrical driving motion to simplify the grasping control and *PF* (pinching then fingertip) sequence had been suggested as a generalized grasping sequence. This two fingers was capable to grasp 6 out of 12 grasping postures, in which one of them was wrap posture for perching task. The proposed versatile 5-DOF fingers was proposed from the two fingers joint significance analysis. The experimental result for verifying the capability of different precision handling for grasping fragile objects had been conducted. This two fingers was capable to grasp 12 out of 12 grasping postures, which have the maximum versatility for two fingers actuator.

Realizing that 5-DOF is already exceeding the operator intuitiveness to control each joint sequentially, hence, the glove-based controller with curled bending sensor had been proposed. Since the bending sensor had an insensitive response for smaller angle, the new sensing structure to improve the sensitivity at a lower angle had been proposed with “V-open sense” structure. With this structure, the bidirectional flexion-extension detection by using unidirectional bending sensor had been enabled. The characterization of the glove system had been explained by comparing the resistance-angle relationship with the conventional structure. The performance of angle detection for each joint had been experimented and the mapping of each posture had been shown. The adeptness of 5-DOF fingers and the response of the intuitive glove system had been verified by performing master-slave control for the whole grasping postures from the taxonomy.

Finally, the performance of the proposed fingers in the practical application had been evaluated. Aerial manipulation with door opening mission had been implemented using the proposed 1-DOF fingers. The aerial robot was first assumed to perch successfully on the door. The manipulator approached the knob by rotating the arm and extending the airbag actuator tip while curving. The knob was then grasped successfully by the fingers and the knob was twisted by the airbag actuator. Aerial perching on the hanging pipe had been implemented using the proposed 3-DOF fingers. The aerial robot was assumed to be able to hover for several second stably and fingers

can wrap the pipe using *PFA* grasping sequence. The teleoperation task of 3-DOF arm position and 2-DOF wrist orientation of slave system controlled by 4-DOF arm added with 7-DOF glove system had been conducted. The strong point and the weakness of the proposed system had been discussed.

## 6.2 Further Development

Though this research had contributed to the design and control of lightweight semi-universal robotics hand research field, various idea and improvement can be suggested as below,

Bidirectional joint motion: Currently the joint is actively driven for flexion motion while passively return by the structure compliances. This unidirectional controlled joint had shown a remarkably result for grasping a wide range of objects, but lack of manipulation capability. In order for the robotics hand to be controlled dexterously, bidirectional structure is indispensable. By optimizing the joint size, structure and mechanism, it would be possible to develop the joint into active bidirectional motion.

Manipulation taxonomy by two fingers: Since this taxonomy is currently not exist for two fingers, it would be better to further study the manipulation ability by the human and classify it into new manipulation taxonomy. This taxonomy should be useful for evaluating the dexterity of the robotics hand with two fingers.

Anthropomorphic fingers structure: The current developed structure is emphasize on large force by weight ratio, therefore, anthropomorphic structure must be simplified into some degree without degrading the capability. However, by developing anthropomorphic two fingers with 9-DOF structure, the potential of robust and dexterous grasping and manipulation might be expanded. The main issue are the optimization of the structure, weight and driving motion including bidirectional joint control.

Prosthetic application: The current issue in prosthetic hand is developing lightweight robotics hand with a wide range of grasping and manipulation capability. This research shows a potential application in prosthetic field. Lightweight robotics hand can reduce the user fatigue and increase the comfortability. The main actuation can be installed on the human body rather than the hand itself. The wearability and portability design of the whole system will be main concern if we

want to use the current fingers structure. The controller can be use EMG sensing of the finger muscle which located on the human forearm.

Bending and tactile sensing on the slave fingers: The current fingers is sensorless and shows a promising result for grasping application. We can expect that adding a tactile sensor for force-torque control and bending sensor for position control on the slave fingers would increase the fingers dexterity. In addition, haptics system would be approachable if the slave fingers have a sensing system installed on it.