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Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

Thesis Outline

Kinematic Analysis and Design of Lower-mobility Parallel Manipulator Based on Kinematically Equivalent Mechanism

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Chapter 1: Introduction

Background

The kinematic analysis and design processes of the lower-mobility parallel manipulators (LMPM) usually focus on symmetric structures, such as all the kinematic chains are identical, base and moving platform are central symmetric or line symmetric. The reason is that the LMPM with symmetric structure has isotropic mobility, which is adaptable to different kinds of tasks. On the other hand, LMPM with asymmetric structure or non-identical chains may have advantages when the task is clearly specified. Therefore, regarding the kinematic analysis and design processes of the LMPM with 3-RS and 3-SR structures, a unified model considering both chain types (e.g. PRS, PSR, RRS, and so on) and various structural parameters will be a convenient tool.

Current Issues

However, the conventional analytical methods based the constraint equations for solving inverse kinematics (IK) of this class of LMPMs are derived from the specific geometric parameters and configurations, such as the configuration where three identical kinematic chains are symmetrically arranged. In addition, the constraint equations are restricted to the choice of the independent pose parameters. As a result, if the configuration or parameters of the mechanism change, the methods may not be suitable, or the constraint equations need to be reformulated. In other words, the analytical expressions of the solutions of the IK are limited to the structural and dimensional conditions, from which constraint equations leading to the closed-form equations are derived, such as the kinematic chain architecture, geometric relationship among joints, and the values of the geometric parameters. Therefore, it is technically difficult to build such a unified model using the conventional analytical method.

Furthermore, due to the complex structures of parallel manipulators, there is no universal and simple index that accurately representing the kinematic performance of all types of parallel manipulators. Developing suitable kinematic performance metrics for parallel manipulators remains an issue. To the best of my knowledge, there has been no performance index considering the characteristics of the RS chain.

Overview of the Thesis

This thesis focuses on the kinematic analysis and design of the class of LMPM, a type of 3-degrees-of-freedom (DOF) parallel manipulators composed of a base and a moving platform with three kinematic chains connecting them. The feature of this class of lower-mobility parallel manipulators is that they become a 3-RS (or 3-SR) structure after locking all the actuators, which is simply termed “primary structure” in the thesis. A new concept “kinematically equivalent mechanism” (KEM) is proposed. Then, based on KEM, a novel iterative method for solving the inverse kinematics of LMPM and a physically meaningful transmission index based on pressure angle are proposed. By combining these two methods, design the LMPM in a unified model will be enabled.

Chapter 2: Kinematically Equivalent Mechanism of Lower-mobility Parallel Manipulator

An idea, kinematically equivalent mechanism (KEM), is proposed. Kinematically equivalent mechanism is able to reflect the practical force transmission and constraint characteristics of an R joint composed of two bearings in the corresponding lower-mobility parallel manipulator, while the motion and constraint characteristics of the kinematically equivalent mechanism are the same as those of the corresponding manipulator once certain actuated joints motion constraints are satisfied.

Chapter 3: An Iterative Method for the Inverse Kinematics of Lower-mobility Parallel Manipulator

An iterative method for solving the inverse kinematics of lower-mobility parallel manipulators based on the kinematically equivalent mechanism is proposed. The method enables to solve the inverse kinematics of such parallel manipulators considering various structural parameters and different sets of output DOFs in a unified modeling, yet without formulating conventional constraint equations. The process in solving the IK of the LMPMs considering different sets of output DOFs and various structural parameters using the proposed method are demonstrated by numerical examples.

Chapter 4: Kinematic Performance Index for Lower-mobility Parallel Manipulator

An intuitive approach to evaluate the kinematic performance of a parallel manipulator is proposed. The proposed transmission index (TI) is based on the pressure angle of the kinematically equivalent mechanism. The proposed TI can be used in not only lower-mobility parallel manipulators but also hybrid parallel manipulators where two actuators exist in each kinematic chain. The proposed approach can indicate both output and constraint singularity conditions with a single index, through simple calculation process without complicated normalization, and can include the width of the revolute joint in the kinematic performance evaluation of this class of parallel manipulators. The effectiveness of TI is verified by numerical examples, such as the singularity analysis, relationships between the maximum joint forces and index values, distribution of TI inside the workspace.

Chapter 5: Kinematic Analysis and Optimal Design of Lower-mobility Parallel Manipulator

A methodology of kinematic performance analysis and design of the lower-mobility parallel manipulator is proposed based on the iterative method for solving inverse kinematics and TI. The kinematic performance is evaluated by the criteria such as the reachable orientation workspace (ROW), global transmission index (GTI), parasitic motion, and good performance orientation workspace (GPOW). The features of the proposed analysis method are shown by numerical results. A multi-objective optimization for a 3-PRS parallel manipulator based on genetic algorithm is implemented and design examples are shown and discussed.

Chapter 6: Conclusion

In general, this thesis proposed a new concept “kinematically equivalent mechanism”, which brings new insights into the analysis and design of the lower-mobility parallel manipulators with 3-RS or 3-SR structures and a new framework for kinematic analysis and design considering more optional choices of architectures and design parameters of LMPMs for the designer.

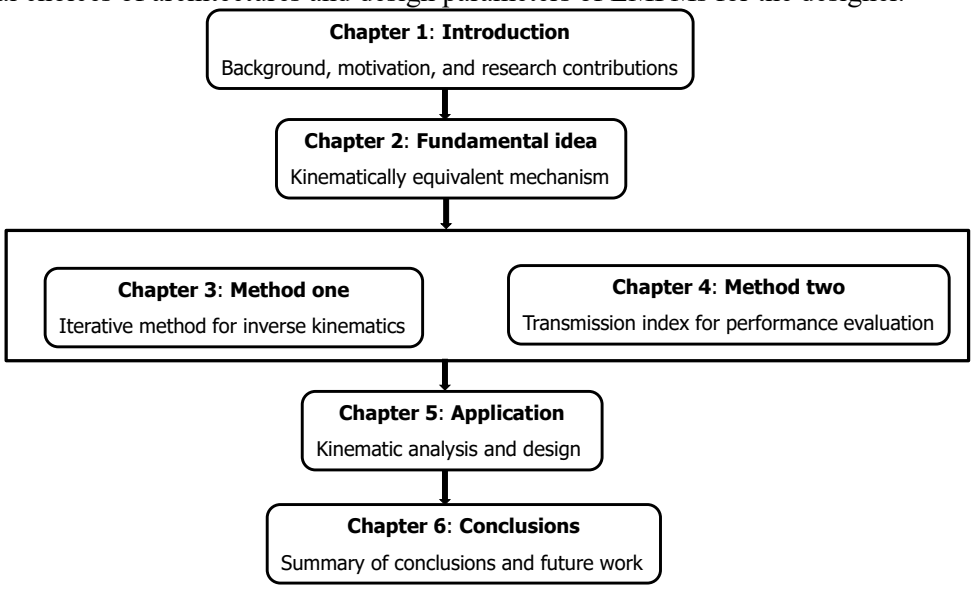

Figure 1Thesis Structure