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Cable-Driven Parallel Robots with Large Translation and Orientation Workspaces

Abstract

Cable-Driven Parallel Robots (CDPRs) also noted as wire-driven robots are parallel manipulators with flexible cables instead of rigid links. A CDPR consists of a base frame, a moving-platform and a set of cables connecting in parallel the moving-platform to the base frame. CDPRs are well-known for their advantageous performance over classical parallel robots in terms of large translation workspace, reconfigurability, large payload capacity and high dynamic performance. They have drawn interests towards industry thanks to their fundamental advantages and capabilities. However, most of the CDPRs provide only limited amplitudes of rotation of the moving-platform due to collisions between the cables and the moving parts.

Novel concepts towards the potential of CDPRs with drastically large orientation workspace have been introduced in literature. One of those concepts suggests using a bi-actuated cable circuit for remote actuation of a parallel mechanism embedded in the moving-platform of CDPRs, forming hybrid manipulators. Those manipulators are hybrid because they combine advantages of large translation workspace of CDPRs and large rotational amplitudes of active wrists. Even though it is a promising concept for augmentation of orientation workspace of CDPRs, to the best of author's knowledge, it has not been realized. Bi-actuated cable circuits, namely, cable-loops are the essence of the hybrid CDPRs with augmented orientation workspace, since they transmit power directly from motor fixed on the ground to the moving-platform. Consequently, the moving -platforms do not require mounted actuators on them, which leads to lower inertia of the moving parts of the manipulators. The objective of this thesis is to design, analyze and build hybrid CDPRs to enlarge the orientation workspace in addition to their large translation workspace by exploiting cable-loops.

This doctoral thesis is composed of five chapters. The first chapter introduces CDPRs, the state of the art related to hybrid manipulators and the fundamental concepts, contribution of the manuscript.

Second chapter dealswith the study, analysis and design of a planar cable-driven parallel crane as the fundamental step for construction of hybrid CDPRs with large translation and orientation workspaces. The primary objective is the investigation of an innovative approach for construction of hybrid CDPRs through cable-loops. Modeling, analysis and optimum design of the proposed hybrid CDPR are presented in the chapter.

A CDPR with an embedded tilt-roll wrist is studied in the third chapter. The manipulator combines the advantages of CDPRs, i.e., a large translational workspace, with those of tilt-roll wrists, namely, drastically large amplitudes of rotations about two axes. The end-effector provides more than forty turns as the amplitude of the tilt and roll. It also exhibits has eight controllable Degree of Freedom (DoF).

Fourth chapter introduces the research work on a CDPR with an embedded parallel spherical wrist with a drastically augmented orientation workspace, i.e., more than fifty turns of rotation about three axes. The under-actuated moving-platform possesses nine-DoF.

Finally, the conclusions are drawn and perspectives for future work are presented in the fifth chapter. The research that had been conducted in the context of this thesis proposes novel solutions for CDPRs with large translation and orientation workspaces. However, there exist many open issues and further improvements to be investigated.

Keywords: Cable-Driven Parallel Robots, Hybrid Robots, Large orientation workspace, Cable loops, Design

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