

Modeling and Control of a Four-Cable Reconfigurable Cable-Driven Parallel Robot

PhD proposal starting as soon as possible (duration: 36 months)

Summary

The PhD thesis investigates three core scientific challenges (C) related to the control of underactuated four-cable reconfigurable cable-driven parallel robots (CDPR):

- (i)** Formulation of the dynamic model for an underactuated reconfigurable CDPR (C1).
- (ii)** Implementing control algorithms to handle reconfigurability and underactuation (C2) in real-time
- (iii)** Analysis and improvement of system stability and precision across variable configurations (C3)

The research draws on existing studies in cable-driven robotics and control systems, proposing novel methods addressing reconfigurable platforms. The outcomes aim to enhance the versatility and efficiency of cable-driven robots, especially in applications that require lightweight, large-area coverage such as automated inspection and environmental interaction.

Background and context

The class of cable-driven parallel robots (CDPRs) with the capability to change cable attachment points continuously is called reconfigurable cable-driven parallel robots (RCDPRs) [1]. Reconfiguration is typically achieved by allowing the cable attachment points on the base frame to move freely along linear rails [2], or mobile platforms, such as UGVs [3] and UAVs [4]. In this context, the researchers from LCFC have developed a prototype of a reconfigurable underactuated cable-driven parallel robot (RU-CDPR) with 4 cables, having attachment points on the moving platform [5,6].

However, despite the benefits of this robot architecture, the state-of-the-art on the dynamics and control of RU-CDPRs is not yet mature from a theoretical point of view. In particular, the following two points are not fully solved: a general method for handling underactuation in RU-CDPRs, and a reconfiguration strategy of the movable points in dynamic operations [7]. To address these questions, **we propose a thesis to develop the mathematical model, control laws and reconfiguration methodology for the RU-CDPR available at the LCFC laboratory.**

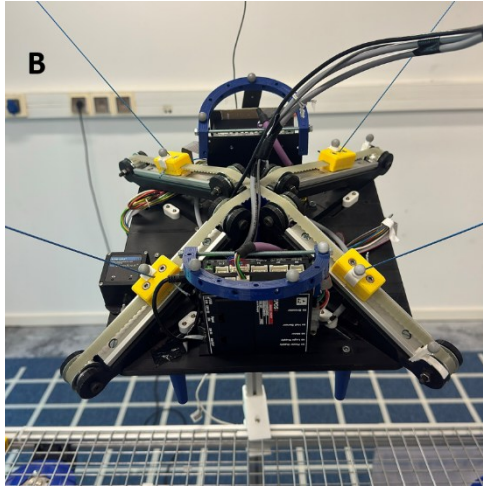


Fig. 1: Prototype of the RU-CDPR at LCFC [6]

The prototype at LCFC has 4 cables and 6 motors for actuation. The prototype includes eight pulleys to guide the cables, four motors mounted at the base to control the cable lengths, and two additional motors embedded on the platform to control the position of the cable attachment points, which move in pairs along two belts using four sliders. Each motor is a Maxon EC-i 52 brushless model with an encoder mounted on the motor and gearbox assembly to measure angular position and speed. The motors are controlled by EPOS4 controllers. The cables are made of nylon, with a diameter of 1.6 mm. The prototype has a cubic frame with dimensions of $1\text{ m} \times 1\text{ m} \times 1\text{ m}$. In addition, an OptiTrack motion capture system measures the position and orientation of the platform.

Research questions

The project will address the following research questions (RQ).

RQ1. How can a dynamic model be formulated to accurately capture the behavior of an underactuated, reconfigurable CDPR across varying geometric configurations and actuation states? (Target C1)

RQ2. Which control algorithms can be developed and implemented in real-time to effectively address the dual challenges of underactuation and reconfigurability in CDPRs? (Target C2)

RQ3. What is the impact of varying the attachment geometry on the moving platform on the robot's controllability, stability, and tension distribution? (Target C3)

Expected Outcomes

1. A **comprehensive modeling framework** for reconfigurable cable-driven parallel robots with mobile attachment points on the moving platform.
2. **Novel control algorithms** capable of handling underactuation and time-varying platform geometry.
3. A **real-time control system** capable of adapting platform configuration dynamically to improve task performance.
4. **Experimental validation** demonstrating enhanced adaptability, precision, and efficiency in real-world or simulated tasks.

Candidate Background

Educational Background

- **Required:** Master's degree (or equivalent) in **Mechanical Engineering, Control Systems, Robotics, Mechatronics, Electrical Engineering**, or a closely related field.
- **Preferred:** Specialization or thesis in **robotics, nonlinear control, or mechanical system modeling**.

Application documents should include:

- A CV (named **CV, Family name**) including previous employment, leadership experience, and two references.
- A motivation letter (named **Motivation letter, Family name**, 1–3 pages) introducing yourself, describing relevant experience (e.g., education, thesis work, research), and outlining future goals and research focus.
- Copies of your bachelor's and/or master's thesis.
- Attested copies of diplomas, transcripts, and other certificates (e.g., TOEFL test results).

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