

Design of a Portable Control Platform for Rod-Driven Continuum Parallel Robots

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To my mother, Gildes Ester.

Success is the sum of small efforts, repeated day in, and day out.

— Robert Collier

Abstract

This project focuses on designing and implementing a portable, modular, and scalable platform alongside a control system tailored for rod-driven continuum parallel robots. The main goal was to develop a versatile mounting solution facilitating efficient robot movement across diverse applications. The project involved the design and construction of the mounting platform, as well as the development of the control interface. A rod-driven continuum parallel robot was designed and implemented, with a focus on miniaturization and optimization of the structure. Additionally, the project aimed to implement a customized language specification for programming the linear actuators, enabling tailored control and operational flexibility. Furthermore, an application was developed to interface with the control system, utilizing the created protocol to ensure seamless communication and precise control.

Acknowledgements

I want to thanks to God...

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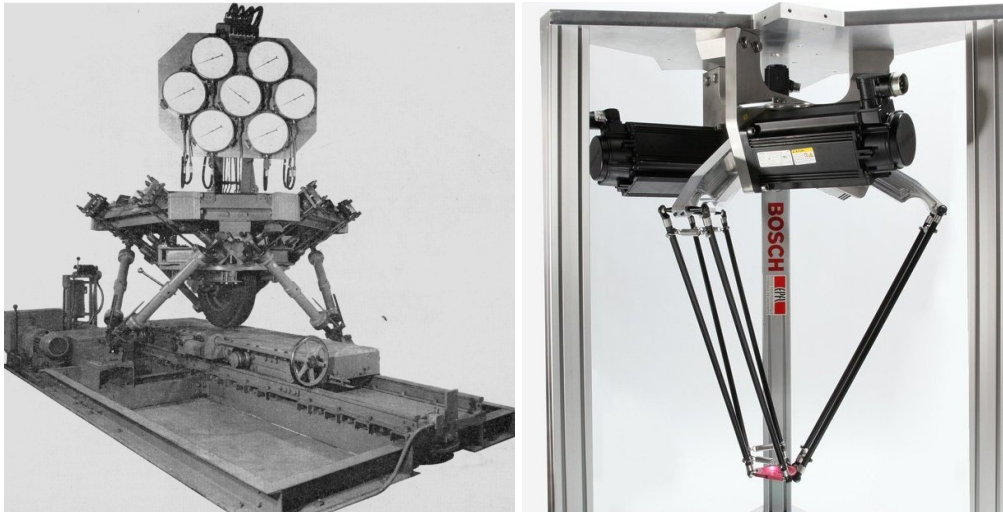
Chapter 1

Introduction

Robots in general can be categorized into serial and parallel types. Serial robots are characterized by a series of linked joints while parallel robots have multiple axes that move in parallel, usually working together to support a single platform.

Parallel robots represent a significant branch in the field of robotics due to their precision and versatility in various applications such as pick-and-place manipulation, simulators, manufacturing, and tooling, among others. As described in [1], these applications span both industry and medicine, leveraging the high rigidity, precision, and speed of these robots to compensate for the performance limitations of serial robots.

The origin of parallel robots dates back to the 1960s with the development of the Gough-Stewart [2] parallel mechanism (Figure 1.1a), which has become one of the most iconic in the field of parallel robotics. Later, in the 1980s, Reymond Clavel designed a robust parallel structure with three translational degrees of freedom and one rotational degree of freedom, as illustrated in Figure 1.1b. This robot, known as the Delta Robot, has become one of the most significant examples in the field of parallel robotics.



(a). Gough-Stewart Platform

Source: Adapted from [2]

(b). Clavel's Delta Robot

Source: Adapted from [3]

Figure 1.1: Traditional parallel robots

Another distinguishing feature of these robots is the presence of multiple closed kinematic chains that connect and move the mobile platforms, in contrast to serial robots, which operate with an open kinematic chain and move in a linear sequence. However, according to Briot and Kahrs [4] the fundamental questions about this class of robots have been addressed. As a result, in recent years, interest in parallel robots has shifted towards exploring new alternatives.

Current research in robotics transcends conventional definitions, pushing the boundaries of this field and fostering new possibilities and innovations. Briot and Kahrs [4] illustrate how parallel manipulators have been integrated into various novel robot types, such as continuum robots, flying robots, cable-driven robots, underactuated robots, multi-fingered hands, and microscale parallel robots. However, this emerging class of robots presents significant scientific challenges in design, modeling, and control. Among these categories, aerial robots, parallel robots, and continuum or soft robots are particularly noteworthy for their ability to venture into new areas due to their lightness and flexibility.

Expanding on these insights, Russo et al. [5] offer a comprehensive review

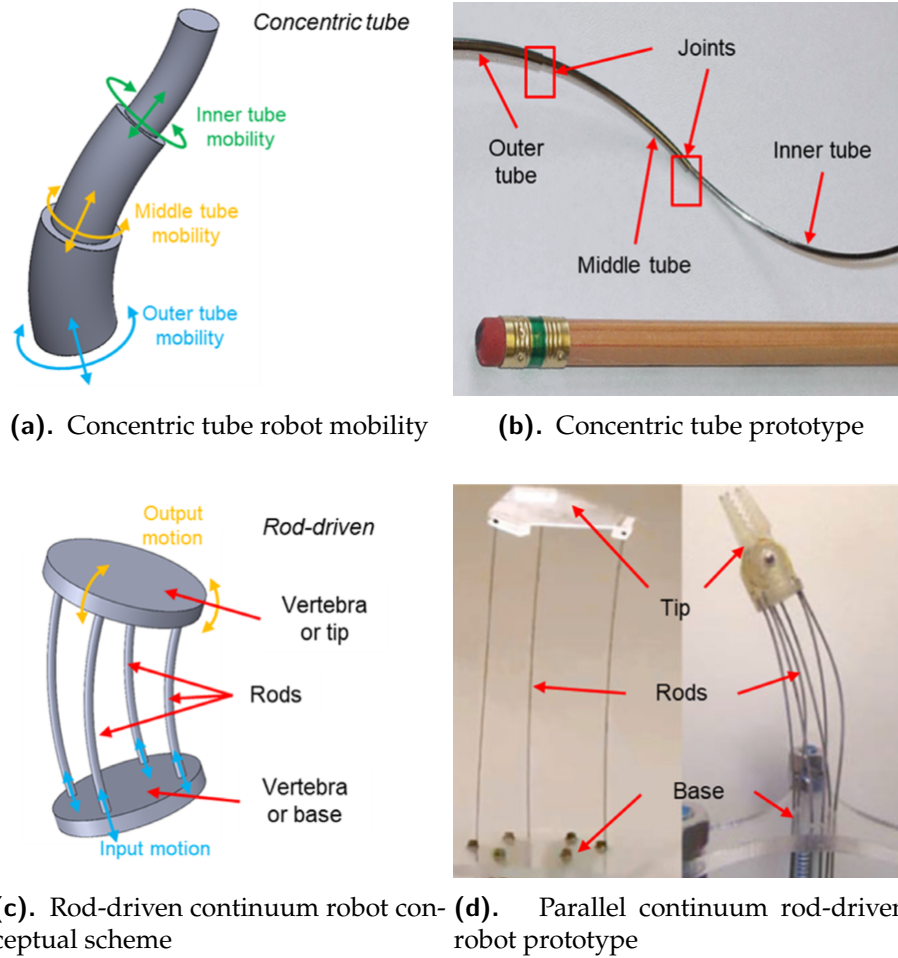


Figure 1.2: Continuum robots with extrinsic actuation

Source: Adapted from [5]

focusing on recent advancements, current limitations, and ongoing challenges in the design, modeling, and control of continuum robots. They classify continuum robots based on their design, distinguishing them by their extrinsic or intrinsic actuation methods. Extrinsic actuation (Figure 1.2) involves transmitting motion from the robot's base along its structure, categorized into three main families depending on the transmission elements used: tendon-driven, concentric tube (Figures 1.2a, 1.2b), and rod-driven robots (Figures 1.2c, 1.2d). Furthermore, robots with intrinsic actuation employ actuators integrated into their structure to generate movement, meaning the actuation occurs within the robot's body.

Current challenges in designing and modeling parallel continuum robots in-

clude improving performance through miniaturization of actuators, integrating with rigid robots, exploring smart materials, precise environmental modeling, and implementing proprioception with new sensors [5]. Modeling efforts also focus on representing interaction environments and improving real-time implementations, alongside standardizing simulation environments. Control challenges involve ensuring precise manipulation and adapting to dynamic environments using advanced sensor technology and adaptive strategies

This project aims to address the efficiency challenges of continuum robots through the miniaturization of their parallel linear actuators. Specifically, it focuses on implementing adaptive control strategies for diverse applications using an extrinsic actuation platform for rod-driven continuum robots. This research endeavors to enhance affordability and user-friendliness, aiming to broaden adoption and usability in practical contexts.

1.1 Objectives

1.1.1 General Objective

To design and develop a portable, modular, and scalable platform with a control system for the actuation of rod-driven continuum parallel robots.

1.1.2 Specific Objectives

- Adapt an existing design of a rod-driven continuum parallel robot, optimizing it for reduced size while maintaining functionality and performance.
- Design linear actuators that provide precise control and enable dexterous movements, ensuring high accuracy and reliability.
- Fabricate all necessary components and assemble a fully functional physical

prototype of the platform, adhering to the design specifications.

- Implement a customized language specification for programming the linear actuators, allowing for tailored control and flexibility in operations.
- Develop an application to interface with the control system, utilizing the created protocol to facilitate seamless communication and control.
- Conduct comprehensive experimental testing and validation of the system, ensuring it meets all performance criteria and operational standards.

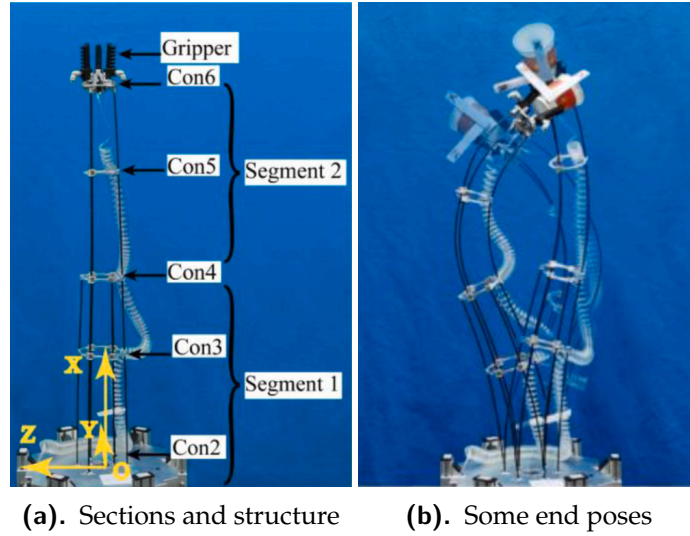
Chapter 2

Target Robot Structure

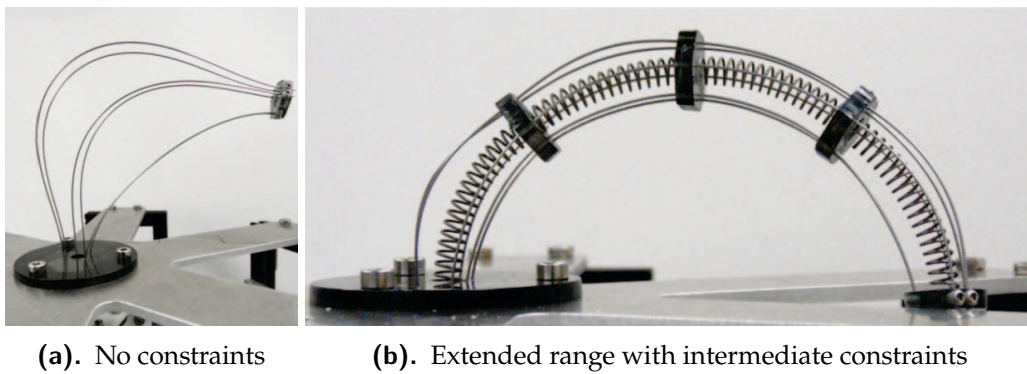
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2.1 Reference Model

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**Figure 2.1:** Reference robot structure

Source: Adapted from [6]

**Figure 2.2:** Constraints and range of motion

Source: Adapted from [7]

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2.2 Rod Material

[Rod definition]

[Table of materials]

[Table of properties of steel material]

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2.3 Design and Dimensions

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2.4 Ring Constraints

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Chapter 3

Linear Actuator

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3.1 Motor

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3.2 Components

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3.3 Specifications

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Chapter 4

Platform Assembly

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4.1 Structural Supports

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4.2 Electronics Case

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4.2.1 Circuit Schematic

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4.3 General Assembly

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Chapter 5

Control System Interface

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5.1 Protocol Specifications

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5.2 Command Line Application

5.2.1 Architecture

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5.2.2 Usage

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5.3 PID Control and Tuning

5.3.1 Autotuning

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5.3.2 System Identification

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Chapter 6

Performance and Results

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And after the second paragraph follows the third paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

After this fourth paragraph, we start a new paragraph sequence. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

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Conclusions

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Future Work and Recommendations

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Appendices