# Soft joint

## Introduction

The field of service robotics has witnessed a rapid surge in demand, prompting researchers worldwide to address the challenges associated with conventional service robots, particularly in terms of agility and adaptability [Reference 1]. To overcome these hurdles, engineers and designers have turned to nature as a source of inspiration, drawing insights from its diverse range of solutions. One promising avenue in this regard is the development of soft robots, which emulate the characteristics and movements observed in living organisms. Soft robots fall under the broader category of nature-inspired robots, which aim to replicate the behaviors and functions found in animals [Reference 2]. These robots encompass various domains, including swimming, flying, and the incorporation of elastic or soft mechanisms [Reference 3].

Traditional service robots often face limitations when confronted with complex and dynamic environments. Their rigid structures hinder their ability to navigate through confined spaces or interact with delicate objects [Reference 4]. In response, there has been a growing emphasis on the development of more flexible robot platforms that enable the design and execution of robust and diverse missions. A critical component in achieving this objective is the implementation of soft mechanisms that can effectively act as joints within these robots, while also maintaining their mechanical properties in real-world scenarios [Reference 5].

The significance of soft mechanisms in service robotics lies in their ability to enhance the motion capabilities and degrees of freedom in robot design [Reference 6]. By incorporating soft joints, these robots can exhibit more natural and fluid movements, mimicking the agility and flexibility observed in their biological counterparts. This adaptability allows them to navigate complex terrains, manipulate objects with precision, and interact safely with humans and their environment. Consequently, the development of an active soft waist for snake-like robots, such as the silkworm, becomes a crucial research objective [Reference 7].

The present research aims to address this need by designing and manufacturing an active soft waist module for snake-like robots, specifically inspired by the silkworm's locomotion [Reference 8]. This module incorporates two helical springs at its center, accompanied by four parallel strings. By utilizing this mechanism, we aim to enhance the motion capabilities of snake-like robots, optimizing their performance in terms of size, weight, and cost [Reference 9]. Through this endeavor, we aspire to contribute to the advancement of service robotics, enabling the development of more versatile and agile robots capable of efficiently navigating complex environments [Reference 10].

## Related works

Considering the history of efforts to develop more flexible robots to our needs, this part tries to discuss them shortly.

[different soft mechanisms]

[different soft robots]

[soft service robots]

[soft mechanisms to improve DOF]

[cons & pros of different mechanisms]

[highlight the importance of your work]

## Proposed method

This research proposes a method to develop an inexpensive soft joint for snake like robots using threads and springs and servo motors in order to improve their moveability and range of motion for this purpose a soft waist has been developed.

### Active soft waist module design

* Calculation + prototype
  + Decide about formulas
  + Design decisions: why 4 threads, why this geometry, why spring
  + Design challenges

## Test and validation

Considering the novelty of the proposed method, a testbed has been specifically designed to facilitate experimentation with the various features of the soft joint. To investigate the workspace and control capabilities of the mechanism, a larger-scale model of the joint has been prototyped, incorporating four identical Dynamixel motors. An Aruco tag has been affixed to the top section of the joint, facilitating positional tracking.

To enable accurate assessment, the entire system is positioned beneath a camera, and the position estimation tools offered by the Robot Operating System (ROS) are employed. Through this setup, the approximate position and velocity of the joint can be derived, allowing for comprehensive analysis.

The initial stage involves validating the positional control of the mechanism. To accomplish this, a Proportional-Integral-Derivative (PID) algorithm is employed, ensuring precise positioning. The coefficients for the PID controller are determined using the Ziegler-Nichols method, which offers an effective approach for parameter tuning and optimization in control systems.

By implementing the PID algorithm and fine-tuning the controller coefficients, the performance of the soft joint in terms of position control can be rigorously evaluated. This validation process is crucial to verify the effectiveness and reliability of the proposed method, enabling further exploration and optimization of the soft joint's capabilities.