Energy Efficient Variable Stiffness Actuators

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Motivation

Variable stiffness actuators can change the apparent output stiffness independent from the output position. By using this type of actuators, a robot can be more or less stiff, depending on the task.

Advantages of using variable stiffness actuators include:

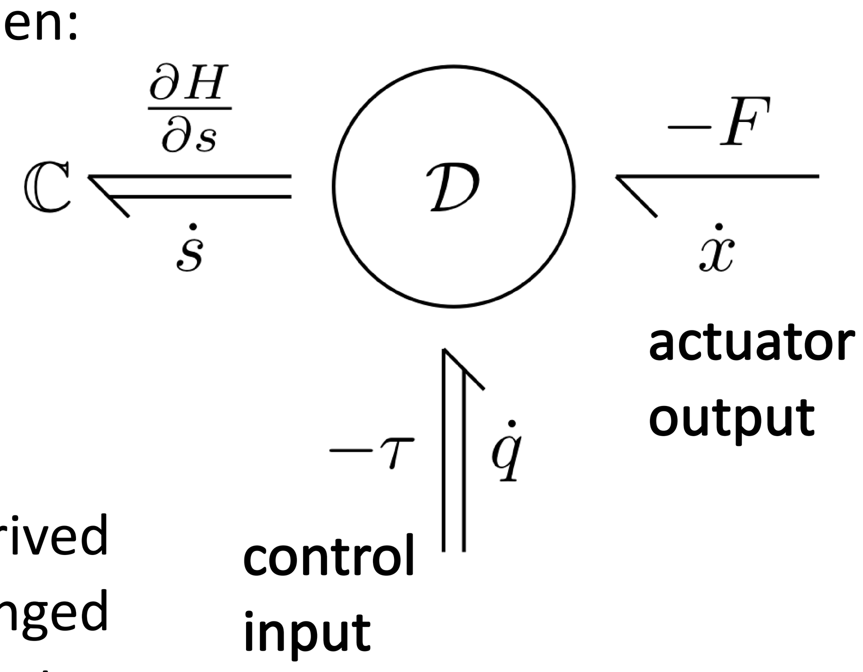
+ **safe human-robot interaction** by properly adjusting joint stiffness;
+ **energy efficient actuation** by tuning the joint stiffness to the desired motion;
+ **increased robustness** with respect to external disturbances.

Port-based Modeling

A port-based model provides valuable insights in power flows between the actuator, the actuated system, and the controller.

The model is based on a bond graph representation, in which the **Dirac structure** $\mathcal{D}$ defines the power flows between:

+ the internal **springs**, which are represented by the C-element;
+ the **control port** actuating the internal degrees of freedom;
+ the **output port**.

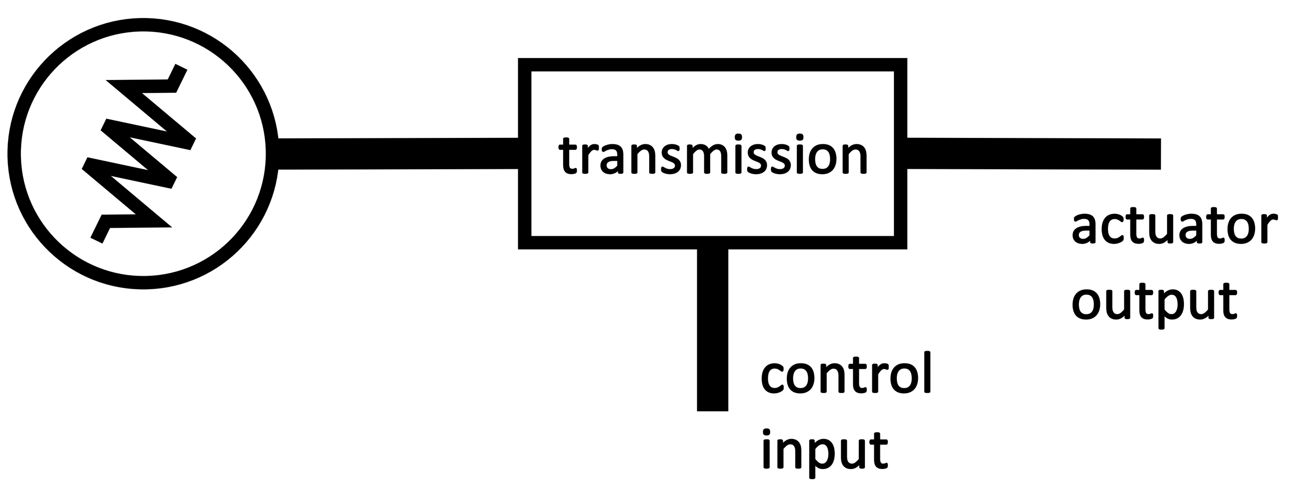


Using this model, design guidelines are derived such that the output stiffness can be changed without supplying energy via the control port.

Design Principle

Variable stiffness actuators are characterized by the following properties:

+ a number of **springs**, internally present in the actuator;
+ a number of **internal degrees of freedom**, that can be actuated via a control input;
+ the **configuration of the degrees of freedom** determines how the springs are sensed at the output and thus determines the **output stiffness**.

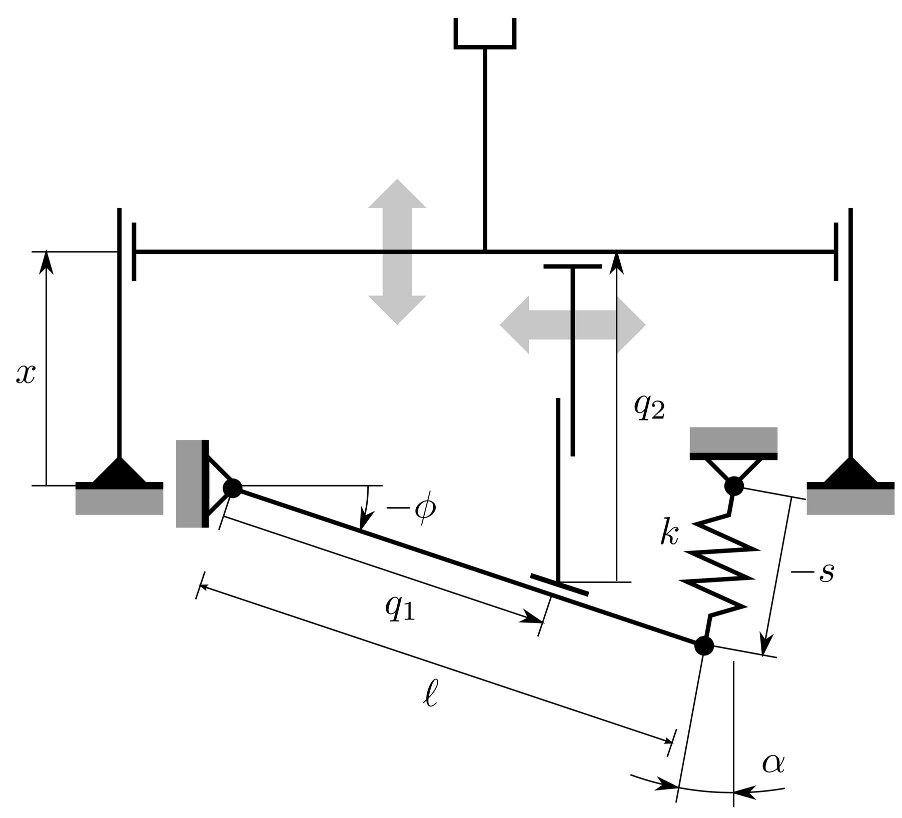


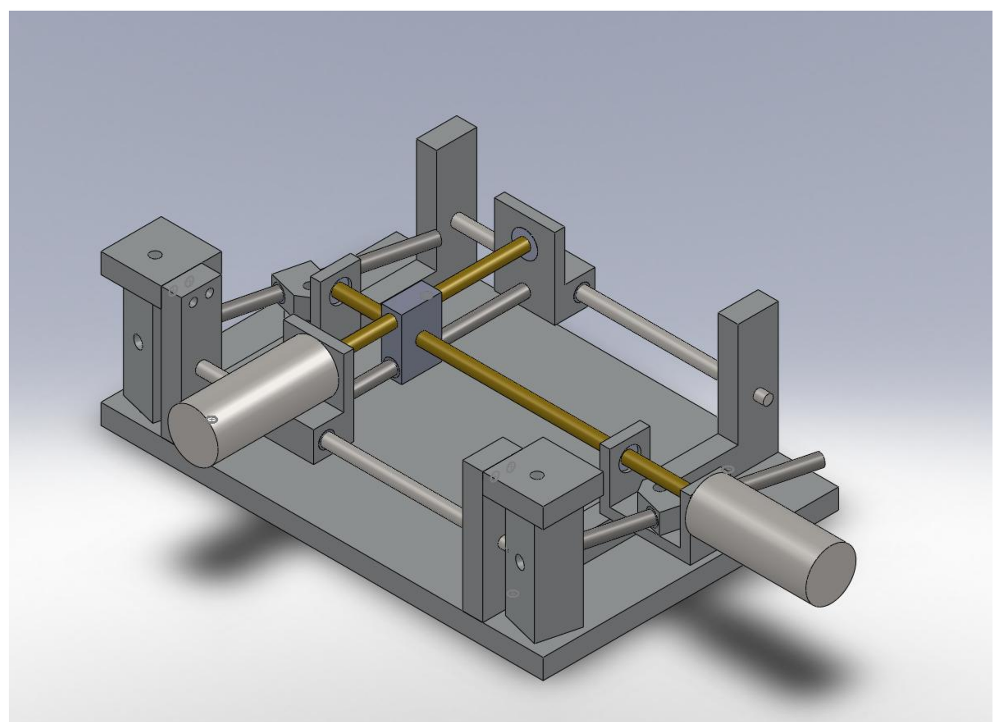
Actuator Design

Starting from the design guidelines, a concept actuator is designed:

+ position and stiffnesss control are **mechanically decoupled**;
+ the apparent output stiffness can be changed without using energy.

A proof of concept **prototype** is realized. This prototype validates the concept and serves as a basis for future actuator designs.

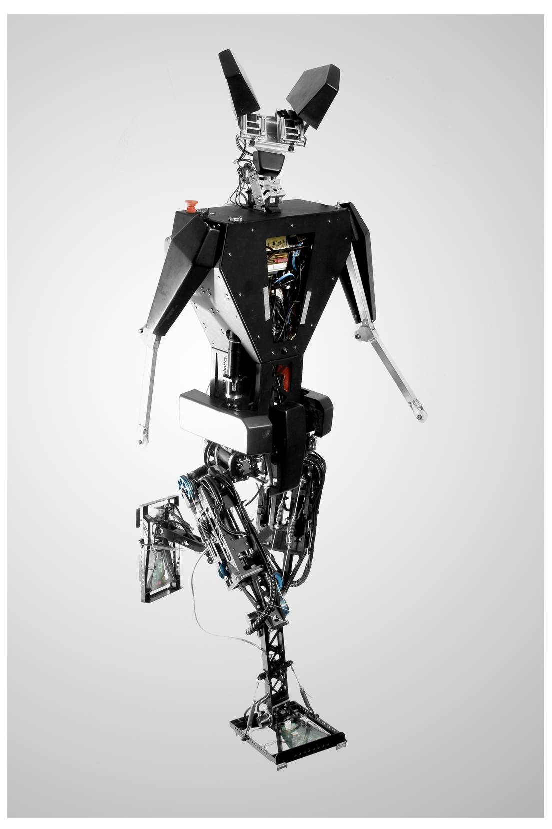




Application to Locomotion

Using variable stiffness actuators in walking robots and leg prosthetics has a number of advantages:

+ the internal springs can be used to **temporarily store energy**, which can be reused for actuation;
+ more energy efficient actuation **increases operating time and range** for walking robots and prosthetic devices;
+ the mechanical compliance of the actuator **increases robustness** with respect to external disturbances;
+ by tuning the apparent output stiffness, the **behaviour** of a prosthetic devices can match more closely the needs of the patient.



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