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Discipline: Engineering and Robotics

Title: Innovative elastic and redundant actuation concepts

Abstract: Typical payload-to-mass ratios of manipulator arms for safe human-robot interaction (cobots) are around 1:10, which is very low compared to those of humans (around 1:1). This can, to a large extent, be explained by our intelligently designed musculoskeletal system. Elasticity of tendons and aponeuroses and redundancy through millions of muscle fibers and sarcomeres enable our muscles to achieve outstanding performance in terms of power-to-weight ratio, energy-efficiency, adaptability and damage-tolerance. Furthermore, multi-articular muscles (i.e. muscles spanning multiple joints) enable energy transfer from proximal to distal body parts, greatly increasing the efficiency of locomotion and manipulation tasks. These two principles can be transferred to robotics – hopefully with similar effects.

The aim of this project is to study how the principles of elasticity and redundancy can be combined in robots with the aim of increasing their energy efficiency. The implementation of elastic elements in actuators has been studied extensively over the past 25 years. Variable stiffness actuators are a particularly exciting development, as they enable the stiffness to be tuned, opening up many new performance-enhancing possibilities. R&MM is a forerunner in the field of variable-stiffness actuation, the MACCEPA being our best-known actuator. It has been implemented in active prostheses, exoskeletons and many other robots by different research groups worldwide.

More recently, R&MM has started looking at how multiple motors can be combined in a single actuator. The +SPEA and Dual-Motor Actuator projects have taught us that the redundancy created by additional motors can improve energy efficiency and dynamic response. The question however remains whether the advantages outweigh the additional weight, cost and complexity of the actuators, especially since redundancy can also be implemented on a robot-level.

The effectiveness of kinematically redundant robots and passive gravity compensation mechanisms has proven that elasticity and redundancy can also have benefits on a robot-level. However, not all possibilities are exploited. Only very few robots exploit multi-articular structures; all existing prototypes are in a research stage. Nevertheless, the energy-transferring capabilities of multi-articular muscles are known to be a key to the energy-efficiency of locomotion.

In this project, you will investigate how the principles of elasticity and redundancy, both on actuator- and robot-level, can be combined in an effective way. As a case study, these concepts will be applied to a 3-DOF manipulator. The aim is to establish design principles for elastic-redundant robots, resulting in a cobot design that delivers unparalleled energy efficiency.

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