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Tunable Compliance in Robotic Hands through Magnetic Field

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Abstract
Compliance is the capability of a body or mechanism to adapt its motion or shape in response to external loads. In the recent years, it is becoming a central feature in robotics to enable a safer robot-environment and human-robot interaction.
Traditional robot and prosthetic hands are mechanically rigid and implement compliance through passive components in series with the transmission (springs or joint-locking mechanisms 1). Alternative approaches include soft robotics that embeds adaptability in the mechanical structures using e.g. soft materials or fluid-inflated chambers. This usually comes at the expenses of precision and controllability [2].
In the context of a standard grasp routine, distinct requirements on compliance emerge. During the approach and grasp phases, high compliance is desirable to ensure collision tolerance, adaptability to object shape, and maximization of the number of contact points. Conversely, during the hold phase, increased stiffness provides stability and resistance against external disturbances [3].
This research investigates the development of variable-stiffness joints for humanoid grippers, with the objective of designing a joint mechanism with compliance tunable with respect to the current grasp phase via magnetic field modulation and magnetoactive elastomers 4.
To achieve controllable stiffness, this study investigates two mechanisms capable of changing physical properties under an external magnetic field. The first mechanism is based on a magnetorheological fluid (MRF) [5]: by varying the applied magnetic field, the yield stress of the fluid, stored in a piston chamber, is adjusted, affecting the piston motion and thereby modulating the resistive force opposing the motion of a revolute joint. The second mechanism relies on a friction-based approach, in which two magneto-active elastomer (MAE) contacting surfaces are laser-engraved into lamellar structures [6]. These lamellas respond to an external magnetic field by aligning with the field lines, altering the friction coefficient between surfaces and, consequently, the motion resistance of the joint.

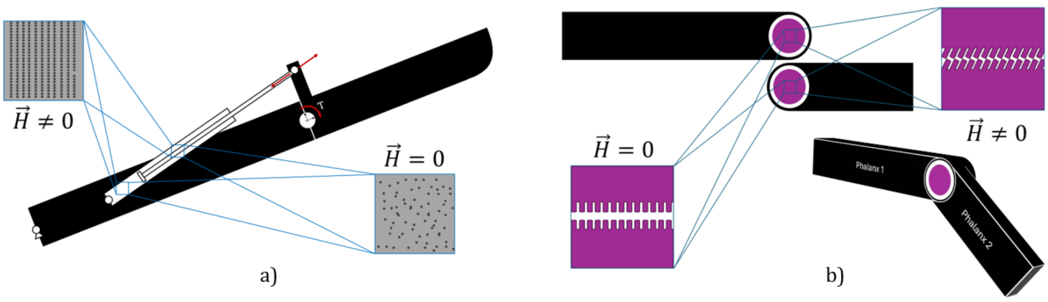

Figure 2: a) Yield-stress based mechanism. b) Friction-based mechanism.

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