High-precision force control using selective compliant mechanisms

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In many applications, robots can benefit from compliant elements integrated in their structure: Shock resistance and superior force control performance are two out of many advantages compared to stiff robots. In contrast, stiff robots are often superior compared to compliant (soft) robots in terms of position accuracy and bandwidth. We are trying to merge the best of these two worlds by combining conventional stiff robots with compliant end effectors. The idea is to extend the established principle of *series elastic actuation* (serial arrangement of actuator and elastic element) [1] to multiple DoFs.
In many applications, compliance is not needed in all DoFs. This requires *selective compliance*, where the robotic structure or the end effector is compliant in designated directions, while the remaining DoFs are stiff. We realized such a system by combining a 4-DoF robotic manipulator with an assembly of springs and linkages on its end effector. This assembly was only compliant in the actuated DoFs and allowed excellent force control [2]. Main drawbacks were the friction and wear caused by the linkages.
To overcome these drawbacks, we go one step further and realize the selective compliant behavior by means of *selective compliance mechanisms* (SCMs): In contrast to mechanisms with rigid members and hinges, SCMs exploit structural flexibility to produce large relative displacements. They present several advantages, such as the absence of wear, friction and backlash as well as reduced maintenance effort [3].

Figure 1. Mouse attached to SCM mounted on a 4-DOF robot.

Similarly to [2], we realized a 4-DoF robot and attached a SCM to its tool point which was compliant in one horizontal and the vertical DOF (Figure 1). We evaluated the system in a demanding task: The robot should follow a mouse attached to the SCM transparently in the two compliant DOFs, while remaining stiff in the other directions. Interaction forces were measured with a high-precision 6D force/torque sensor mounted between the selective compliant element and the robot. Being attached to the robot, the mouse could move along a runway without any visible influence on her walking behavior. This experiment is a first but promising proof-of-concept of the SCM principle. The concept could largely expand the applicability of industrial robots, by enabling them to perform tasks that require high-precision, multidimensional, and selective force/position control capabilities, such as soldering or assembling.

References

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