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A Variable-Stiffness Robot for Force-Sensitive Applications

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Abstract—Robots with adjustable joint stiffness can ensure safety and manipulation reliability in force-sensitive applications. Existing robots use six-axis force/torque sensors at the end-effector to sense the output force and control the output compliance. External sensors are costly, bulky, and cannot be used to offer active link compliance. To account for link compliance and avoid link collision, robots need to have a torque-controlled actuator at each joint. This paper presents a variable-stiffness robot that employs a torque-controlled actuator at each joint. Unlike existing torque-controlled actuators, the proposed actuator has a compact structure and high output moment rigidity. Only encoders are required to sense and control the output torque to exhibit a wide range of controlled stiffness. The end-effector compliance in each direction can be adjusted by varying the compliance contribution of each joint. Design, modeling, and compliance control of the robot are presented. Experiments of the robot in force-sensitive applications demonstrate the accuracy and stability of end-effector compliance control. It is expected that this variable-stiffness robot can be used to interact safely with humans or the environment.