Towards variable impedance assembly: the VSA peg-in-hole

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Robotic assembly could be taken to a whole new level by employing Variable Impedance Actuators (VIA). The current generation of industrial manipulators require high precision, at the cost of the use of expensive hardware, sensors and the application of advanced control techniques. We show how an accurate peg-in-hole assembly task can be easily achieved with nothing but cheap position sensors when resourcing to VIAs, by exploiting the intrinsic mechanical elasticity of the actuator units. We do so by using Variable Stiffness Actuators (VSA) non-planar manipulators in a bimanual peg-in-hole assembly task. The VIA approach [1] has the extra benefit of guaranteeing safety in human-robot interaction [2].

The peg-in-hole task [3] consists in inserting a cylindrical peg in a round hole, where the position and orientation of the hole with respect to the peg are uncertain. The literature on the problem shows how passive compliance is necessary [4] to avoid insertion problems (jamming and wedging) even when recurring to active impedance control, with classic passive methods like the RCC and its variants resulting unsuitable for difficult assemblies [5].

The control used to perform the task is pure motor-side position control with gravity compensation. The VSAs are thus used in their servo mode, where position and stiffness set-points can be imposed. A blind search algorithm has been derived in order to resolve uncertainties in the position of the peg and hole and bring the manipulator in a chamfer crossing condition, by sampling an exhaustive search trajectory around the expected position of the hole and randomly visiting the sampled points. During the search phase, a state machine randomly tries to insert the peg, and checks for insertions by analyzing the maximum cartesian displacement along the axis direction during thrusts. The insertion phase is tackled by implementing an induced oscillation motion in order to win insertion frictions thus avoiding jamming, and accommodating for orientation uncertainties. Oscillation gains at each joint have been designed to obtain a motion similar to that a human would have performed.

In the experimental setup the VSA humanoid torso CubeBot [6] has been used to insert a chamfered 29.5mm cylindrical peg into a 30mm round hole printed with ABS plastic. The peg and hole are maintained by the closed hand clamps. Since the three dimensional round peg-in-hole task requires 5DoF to be executed, but each arm of the robot only allows for 4DoF manipulation, both arms needed to be used. The sensory information available in order to resolve the uncertainties and perform the insertion amounts only to the link positions measured by low quality potentiometers. While during insertion the stiffness presets have been kept constant to the lowest value allowed by the actuators, the non-linearity of VIA impedance characteristics causes an increase along the insertion axis that help contrast insertion frictions forces.

Experimental results prove the efficiency of the strategy. Insertion experiments for 29mm and 29.5mm pegs are demonstrated on the attached video at http://youtu.be/7Ipu_P8_eCAq

REFERENCES


