Institute of Mechatronic Systems
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Towards Human-Robot Collaboration with Parallel Robots by Kinetostatic Analysis, Impedance Control and Contact Detection

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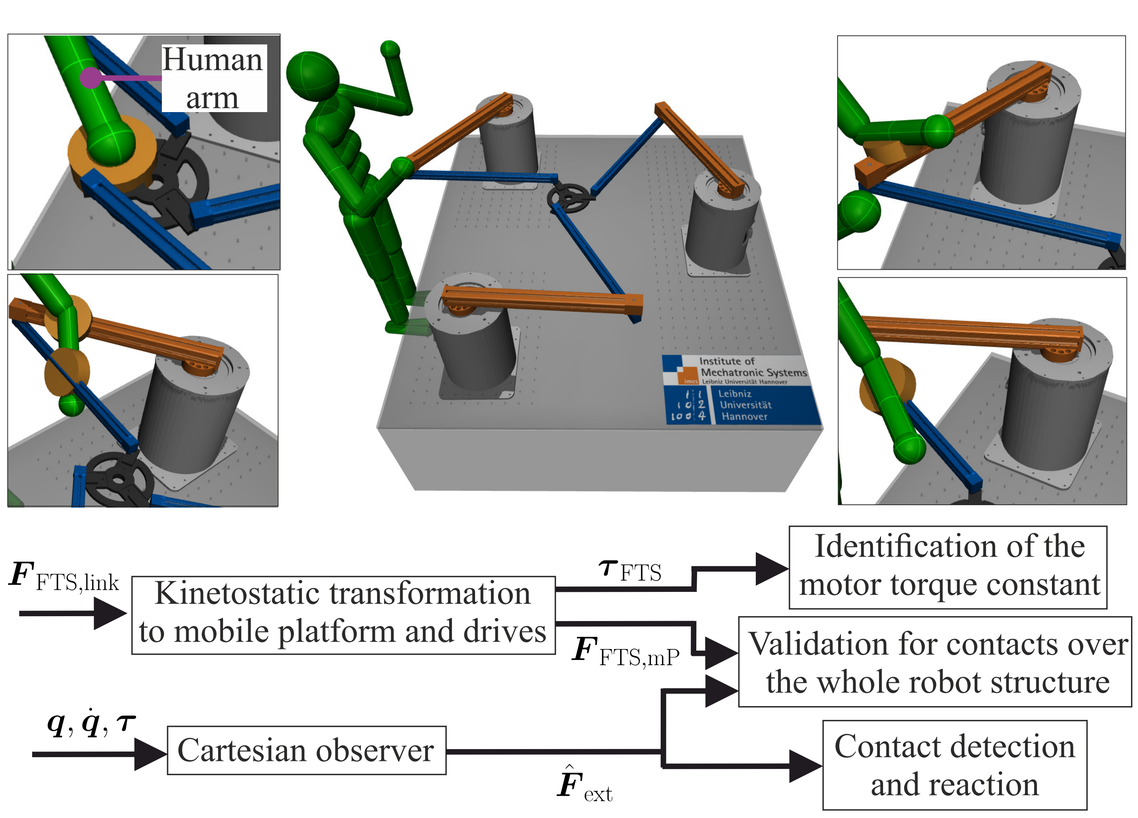
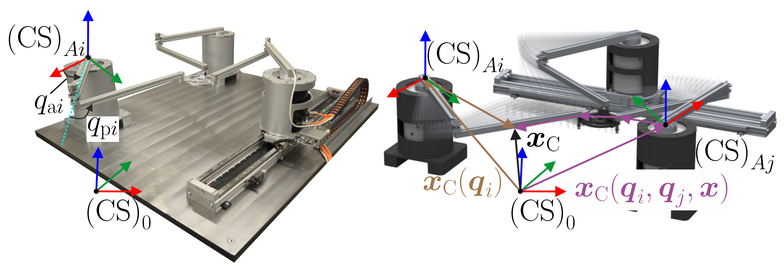
Research Question & Contributions

- Parallel robots (PRs) are characterized by drives mounted fixed to the base reducing the moving mass and allowing higher speeds while maintaining the same energy thresholds regarding human-robot collaboration. Due to the parallel kinematic chains, the risk of contact increases → *How is it possible to detect contacts on the entire structure of a parallel robot?*
- Kinetostatic model transforms contact forces of any contact point of a PR to the mobile platform and to the actuators
- Robot reacts sensitively with a low-impedance-controlled response in case of a collision and clamping at the robot structure, which is detected by a generalized momentum-based disturbance observer
- Comparison is made with a Kalman filter and a second-order sliding-mode observer based on the generalized momenta in terms of error and detection time



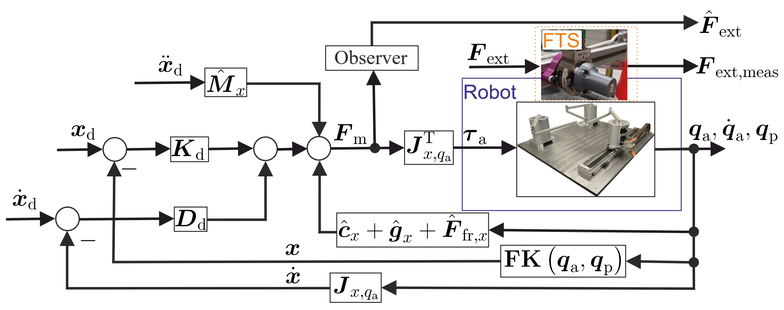
Modeling & Control

Kinetostatic Analysis



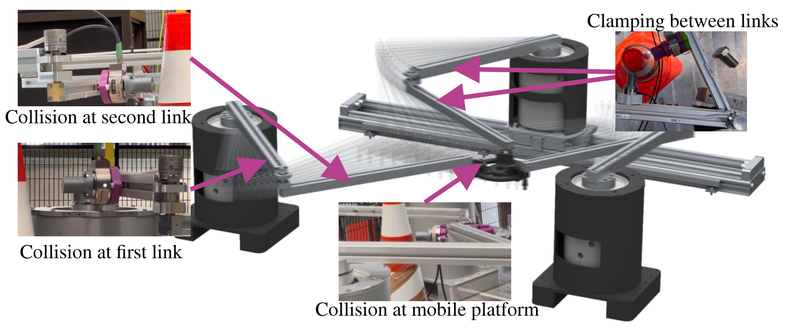
- Kinetostatic projection of an arbitrary contact location to the platform and actuators

Test Bench



- Cartesian control and observer at $1\,\mathrm{kHz}$
- Validation with force-torque sensors

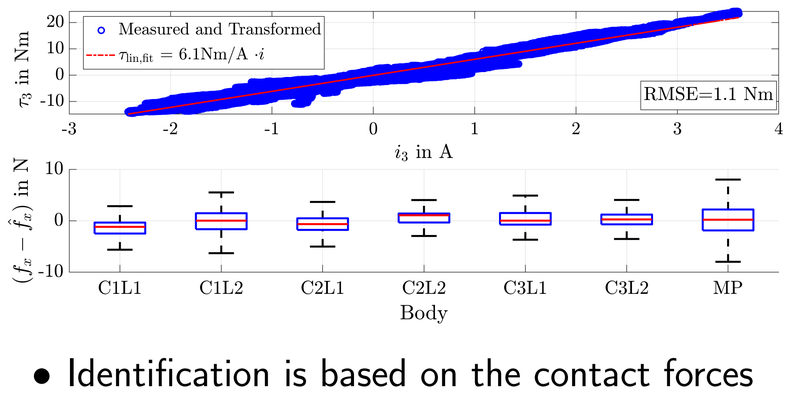
Contact Experiments



- Collision at the structure and clamping between links at velocities of $0.4\text{–}0.9\,\mathrm{m/s}$

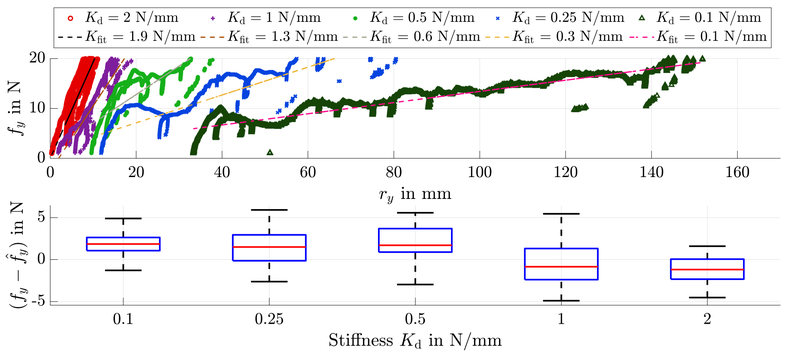
Contact Detection & Reaction

Identification of Motor Torque Constant



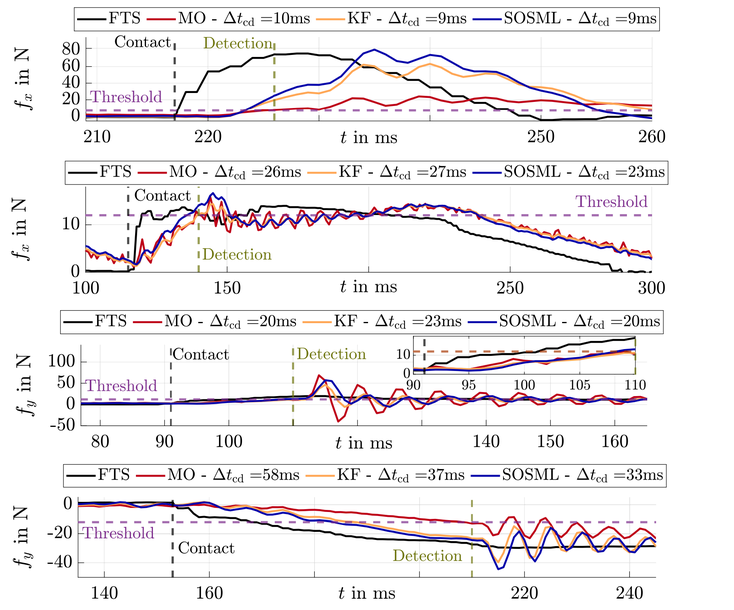
- Identification is based on the contact forces transformed to the drives at the six links and the platform
- Validation is performed with an error of $10\,\mathrm{N}$ in an unknown configuration, where contact forces are applied on all seven bodies

Impedance Control and Observer



- Stepwise constant forces on the mobile platform are used to validate the stiffness $0.1\,\frac{\mathrm{N}}{\mathrm{mm}} < K_{\mathrm{d}} < 2\,\frac{\mathrm{N}}{\mathrm{mm}}$ of the impedance control
- Force estimation error of only $5\,\mathrm{N}$ occurs for softest and stiffest control

Collision and Clamping Detection



- Detection within $9\text{–}58\,\mathrm{ms}$

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