Institute of Mechatronic Systems
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Combining Proprioceptive-Data-Driven Algorithms with Physical Modeling for Contact Detection and Reaction of Safe Parallel Robots

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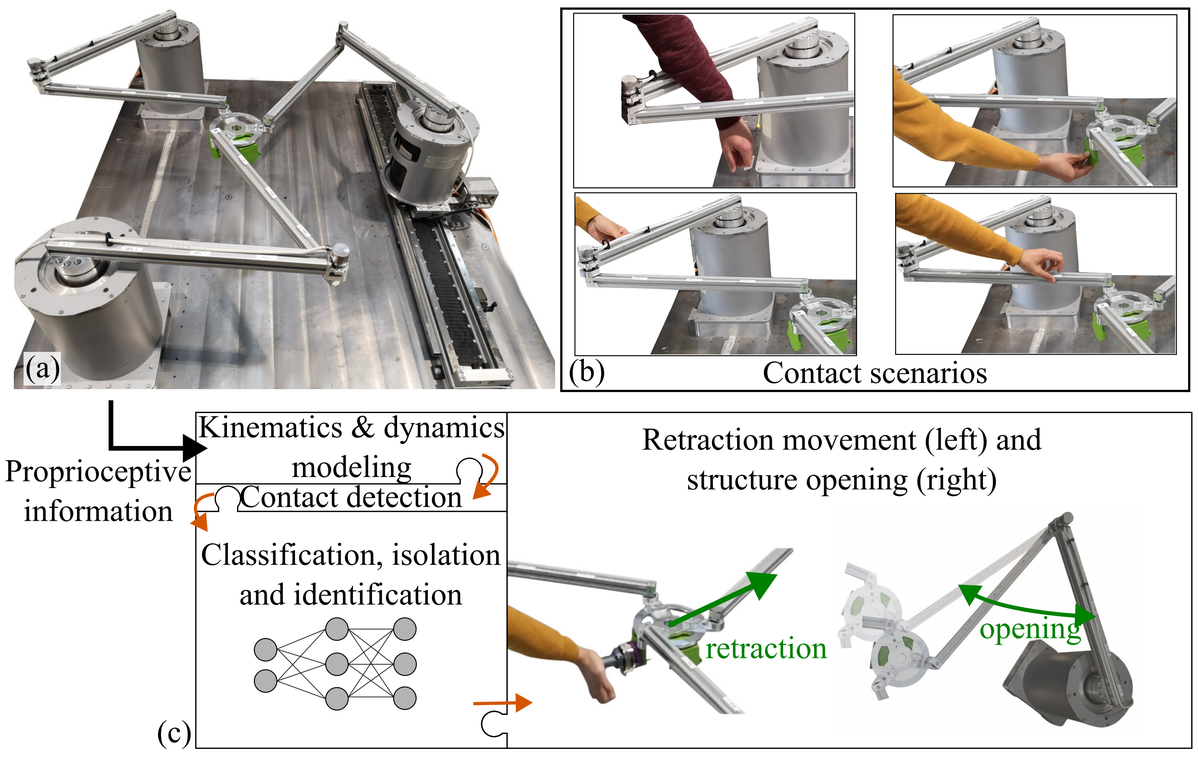
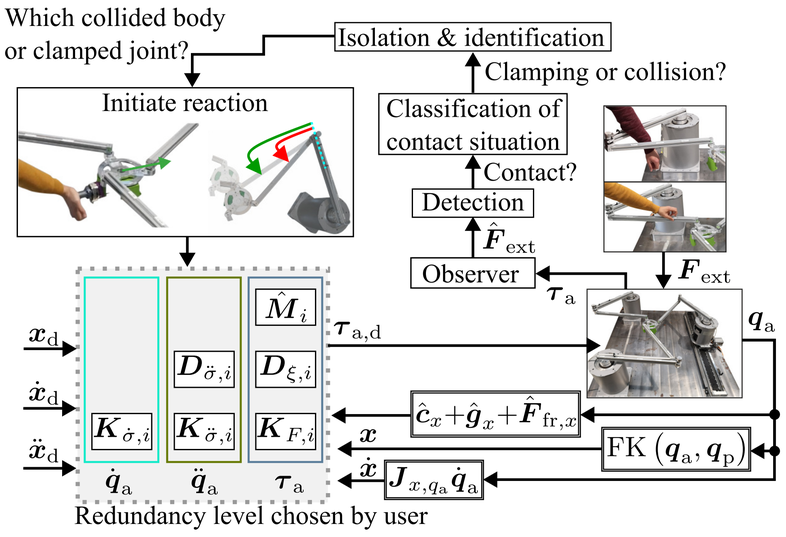
Research Question & Contributions

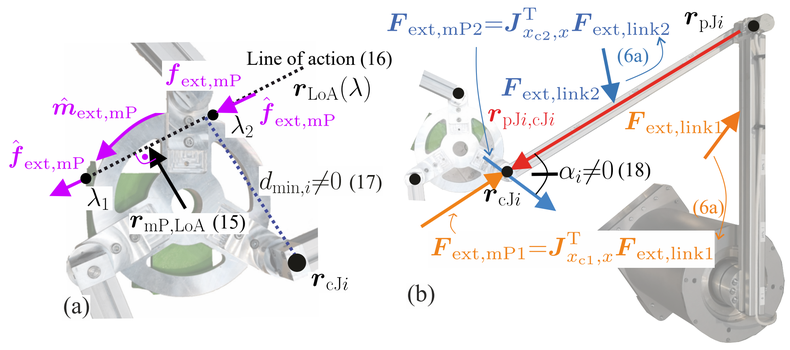
- Parallel robots are characterized by drives mounted fixed to the base. Reduced moving masses allow higher speeds while maintaining the same energy thresholds regarding human-robot collaboration. Due to the parallel kinematic chains, the risk of collision and clamping contact increases. → **How do collisions and clamping contacts affect the dynamics of a parallel robot? Does this insight allow us to estimate the type and location on the entire structure of a parallel robot?**
- Physically modeled features allow classification and generalization to contacts over the entire robot body in unknown joint-angle configurations.
- Multiple reaction strategies based on the previously obtained information are introduced in a redundancy-resolution scheme to incorporate the collision point and clamping joint explicitly.

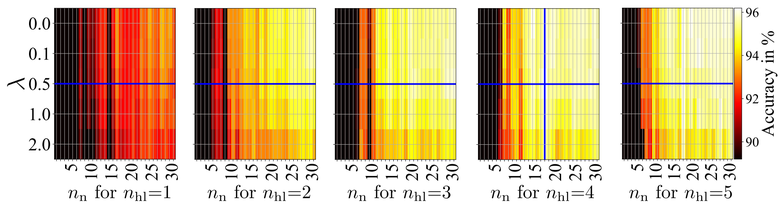


Classification via Combined Physical and Data-Driven Modeling

Approach for Safe Parallel Robots	Hypothesis Formulation	Hyperparamter Optimization







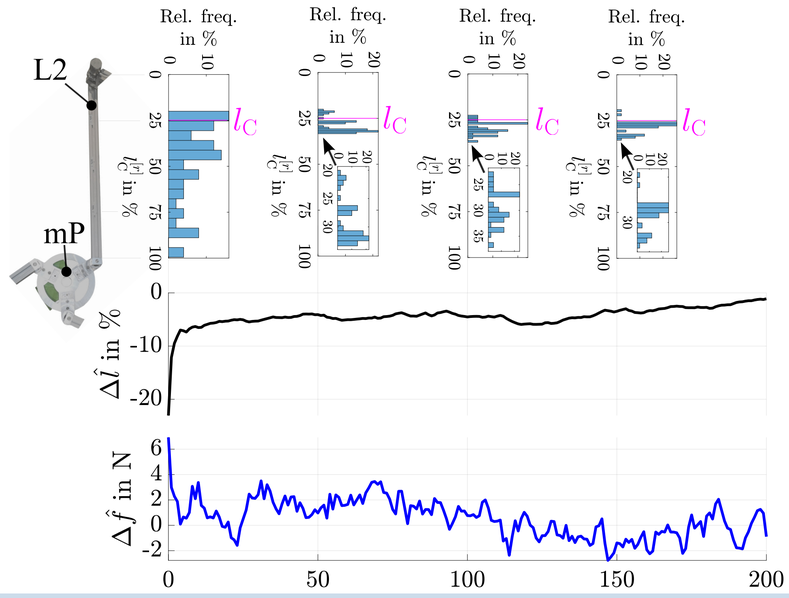
- Platform and chain contacts differ by minimal distance $d_{\mathrm{min},i}$
- Link collisions differ by angle α_i
- Approach: hyperparameter are regularization factor (λ), number of hidden layers (n_{hl}) and neurons per layer (n_{neu})
- Heatmap with cross-validation results for network structure
- Result: 4 layers with 17 neurons in each layer

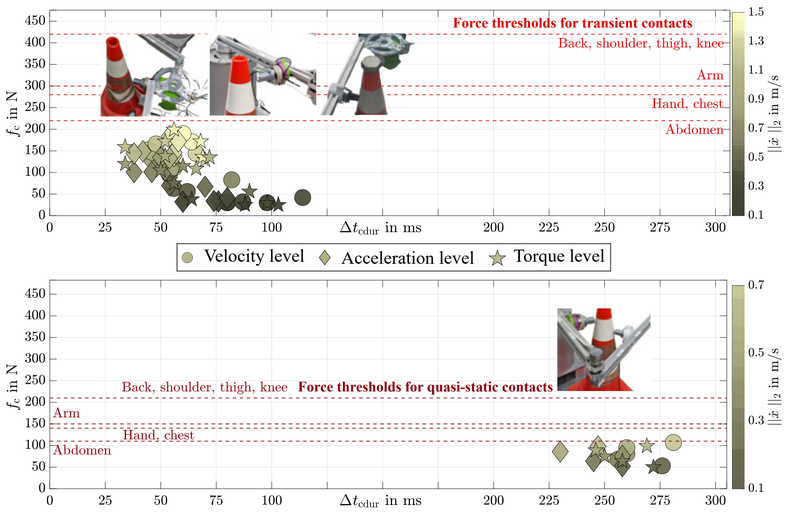
Neural Networks & Particle Filter for Contact Reaction

Collided-Body Classification	Isolation and Identification	Transient and Quasi-Static Contacts

Ground truth \ Predicted via FNN with an accuracy of 83.98%	C1L1	C1L2	C2L1	C2L2	C3L1	C3L2	mP
C1L1	90.4%					0.0%	9.6%
C1L2		74.8%	6.6%				18.5%
C2L1		0.0%	81.7%				18.3%
C2L2				99.9%	0.1%		
C3L1				5.5%	94.5%		
C3L2	19.9%					75.5%	4.6%
mP		15.1%	0.8%	8.9%		1.4%	73.8%

- Feature engineering and classification at 1 kHz
- Confusion matrix with test data of collisions in unknown contact scenarios
- Classification's output decides on the collision isolation and identification





72 contacts with maximum velocities of 1.5 m/s