The Tri-State Active Docking Interface of STORM: Self-configurable and Transformable Omni-directional Robotic Modules

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Project Motivations

The motivations of the project presented in this poster stem from **STORM**, an acronym for Self-configurable and Transformable Omni-directional Robotic Modules.

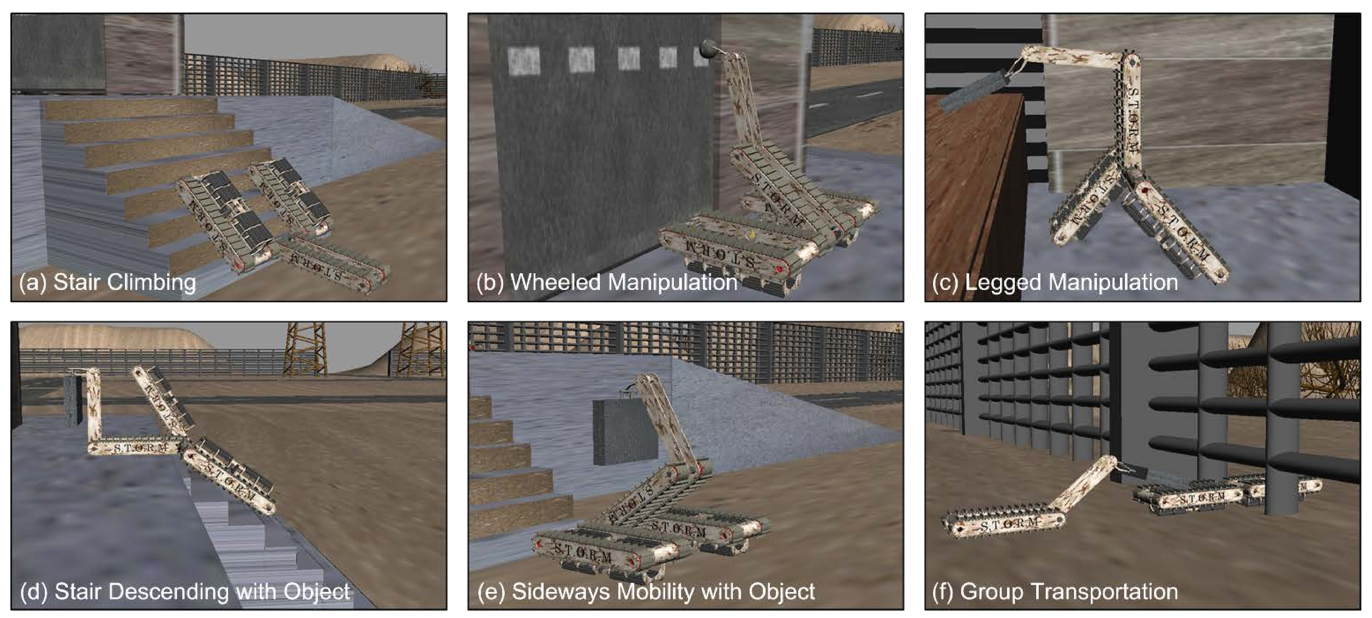
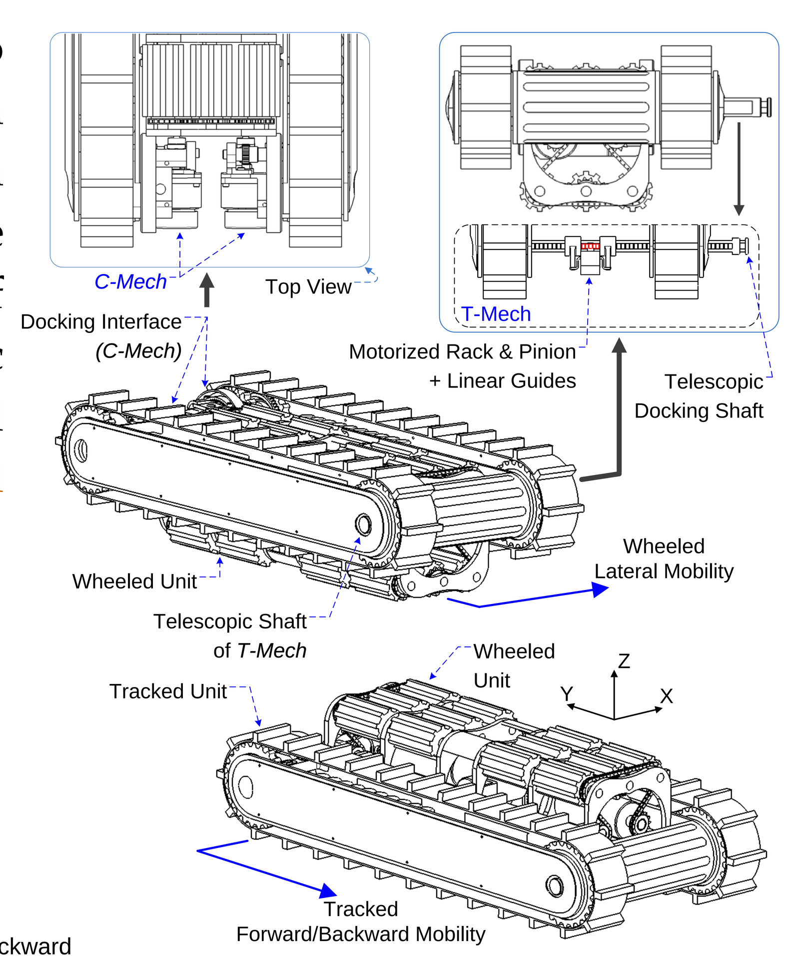


Figure 1: Sample adaptive formations of STORM for mobility and manipulation on rough terrain

STORM represents an on-going initiative of modular and omni-directional mobile robotics for rugged terrain adaptive mobility and manipulation. The objective is to develop a modular robotic technology capable of adapting to the unstructured topology of an urban terrain, while being rigid enough in the docked formations to exhibit resilience and strength comparable to a traditional rigid-structure mobile robot.

STORM Modules

STORM is comprised of two independent modules: a locomotion module and a manipulation module. The locomotion module consists of a hybrid symmetric combination of wheels and tracks with three-dimensional omni-directional mobility.



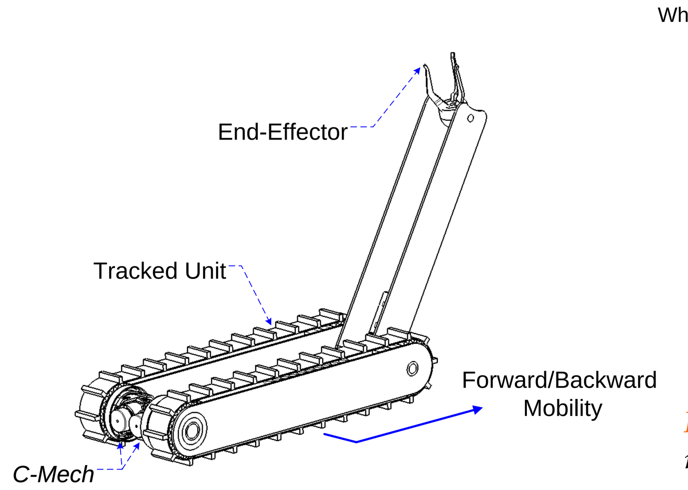


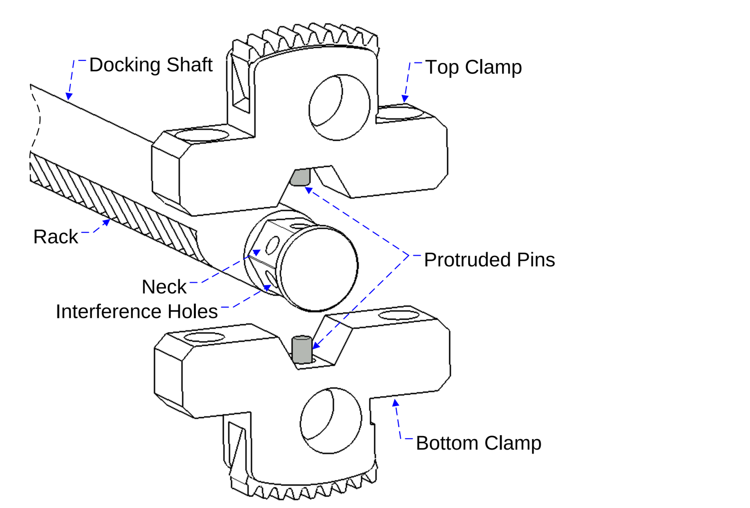
Figure 2: The locomotion and manipulation modules of STORM with the T-Mech and C-Mech components of the docking interface

The manipulation module consists of two tracked units with differential steering and a one-link arm with an end-effector.

The docking interface of STORM is carried jointly by the two modules, where the male part (*T-Mech*) is typically carried by the locomotion module, and the female part (*C-Mech*) by the manipulation module.

Active Docking Interface

The male (*T-Mech*) component of the docking interface consists of a telescopic non-back-drivable shaft driven by a rack and pinion mechanism that can be deployed from either side of the locomotion module.



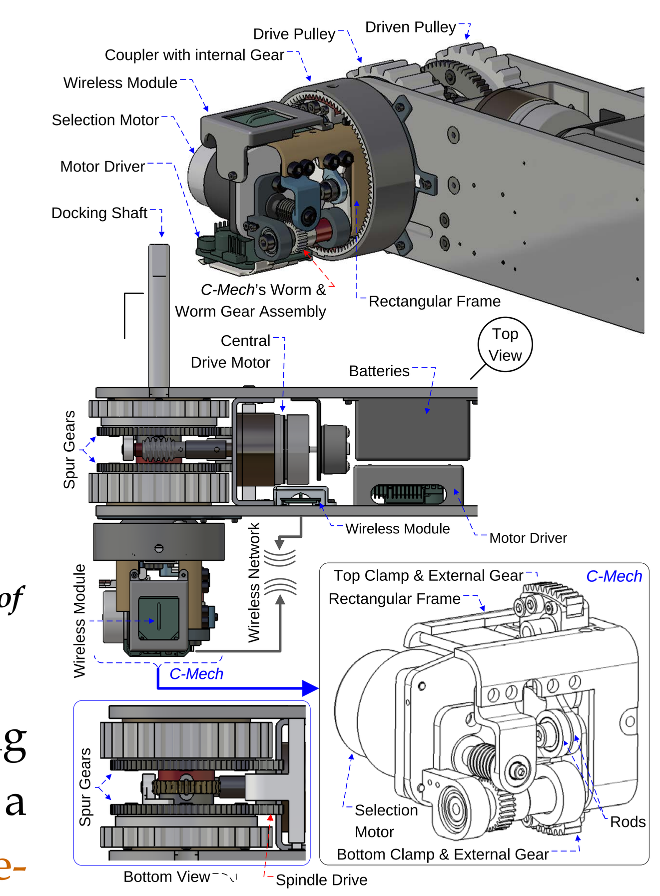


Figure 3: The male (T-Mech) and female (C-Mech) components of STORM's docking interface

The female (*C-Mech*) component of the docking interface consists of a clamping system actuated by a dual-rod slider crank mechanism, which re-circulates the central motor's torque to initiate three independent modes of operation: **Drive**, **Neutral**, and **Clamp**.

Modes of Operation

The active docking interface operates in three independent modes:

- **Drive mode**: where the sliders' external gears engage the internal gear of the coupler. This circulates the torque to drive the pulleys.
- **Neutral mode**: where the sliders disengage the internal gear to enable the *C-Mech*'s idle rotation inside the coupler for alignment purposes.

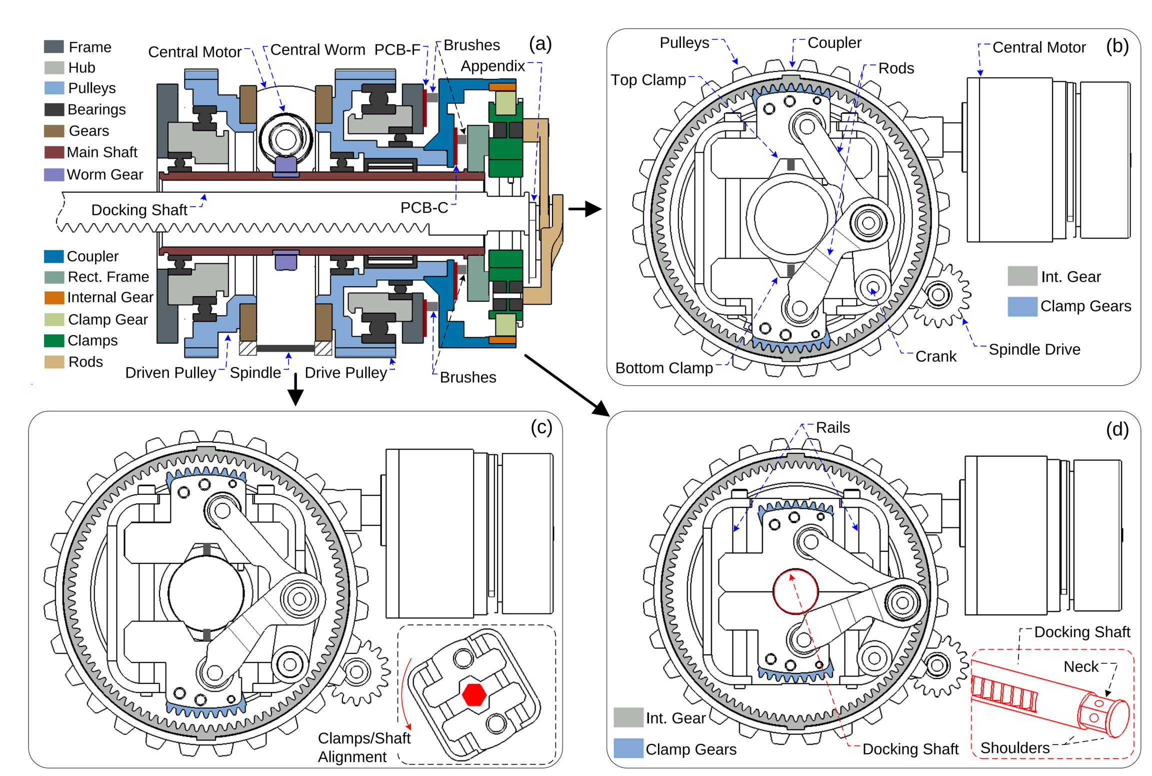


Figure 4: Transmission schematic and three modes of operation of the C-Mech: (a) Drive, (b) Neutral, (c) Clamp

- **Clamp mode**: where the sliders clamp on the docking shaft and create an active joint around which the central motor rotates the module relative to its neighbors.

Sample Additional STORM Configurations

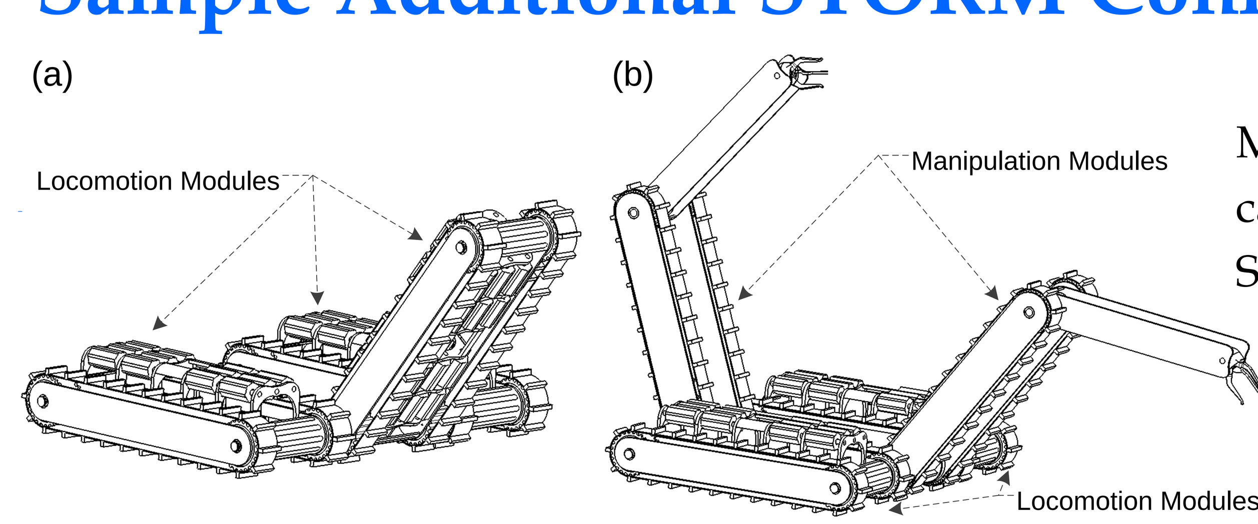


Figure 5: (a) 3-module, (b) 4-module dual-arm formations of STORM

Many additional formations can be generated with STORM and its docking interface, such as the 3-module and 4-module dual-arm formations.

Optimal Kinematics

The dual-rod slider crank mechanism of the docking interface exhibits unique kinematic properties, where the two sliders do not travel the same distance for the same crank rotation.

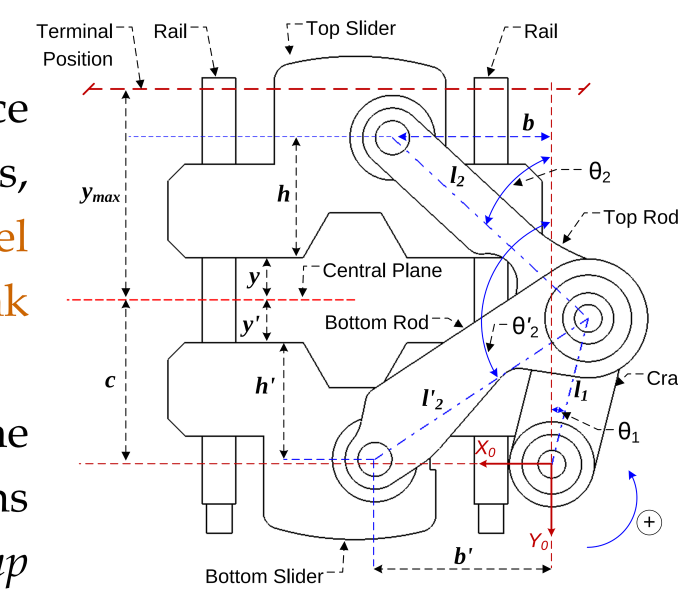


Figure 6: The kinematics of the dual-rod slider crank mechanism

To enable the mechanism to meet the terminal boundary conditions corresponding to the *drive* and *clamp* mode, an optimization problem can be formulated whose optimal solution generates values for b', h' that maximize the mechanism efficiency ξ and minimize the displacement offset error $e = y + y'$.

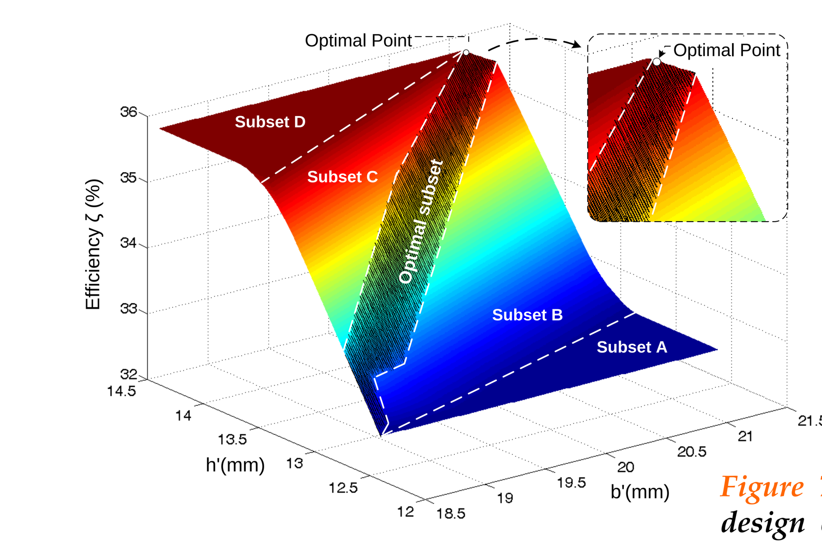


Figure 7: Meshed solution of the optimal kinematic design of the dual-rod slider crank mechanism

Dynamic Analysis and Prototype

The optimal dimensions of b', h', enable the sliders of the dual-rod slider crank mechanism to initiate the drive/clamp mode at the same time despite the different velocity and acceleration profiles exhibited in the middle stroke.

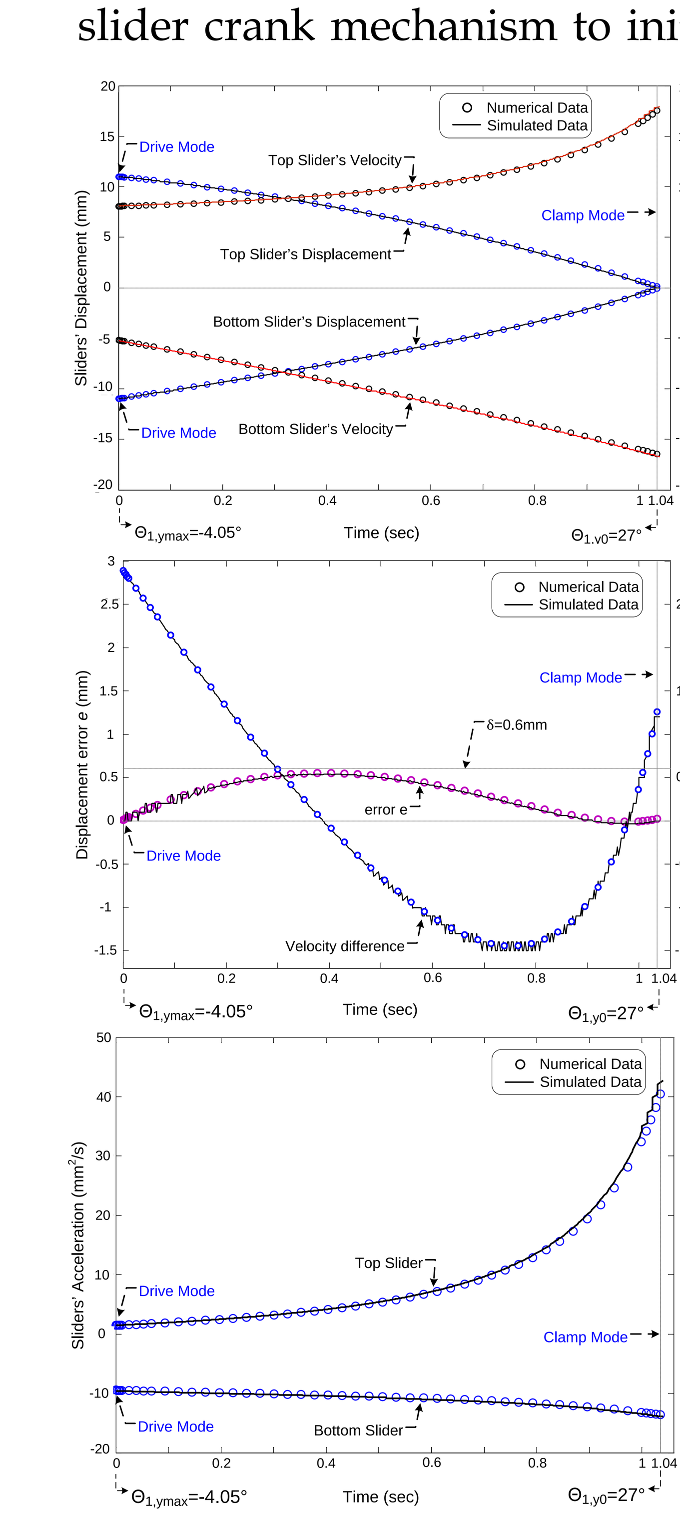
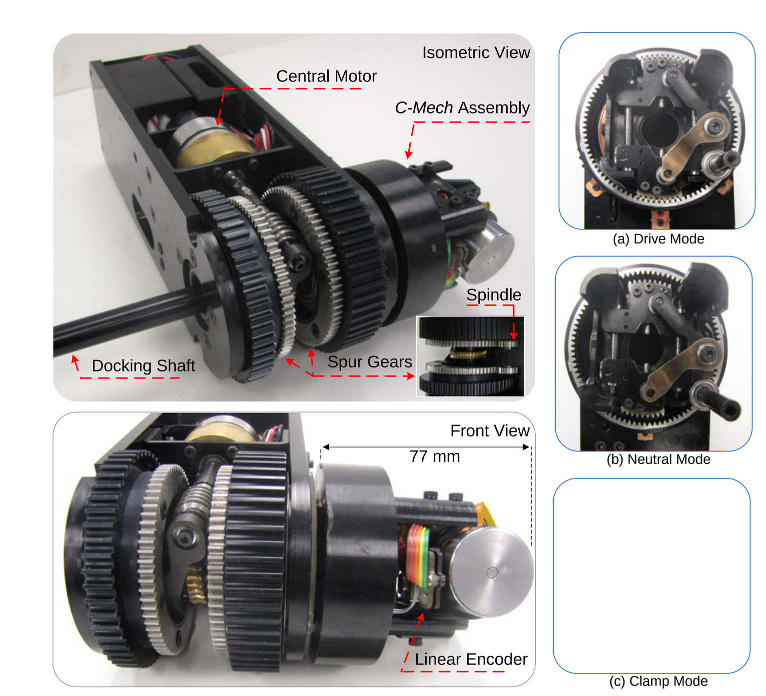


Figure 8: Position, velocity, acceleration and displacement and velocity offsets for top and bottom sliders



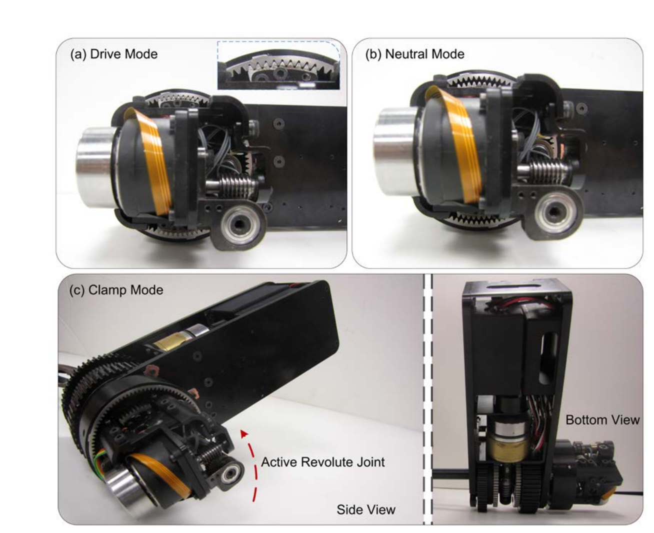


Figure 9: Prototype of the docking interface connected to a small mobile robot, with details showing the drive, neutral and clamp modes