# NRI: FND: Controllable Compliance: A New Robotic Arm for Contact-Rich Manipulation

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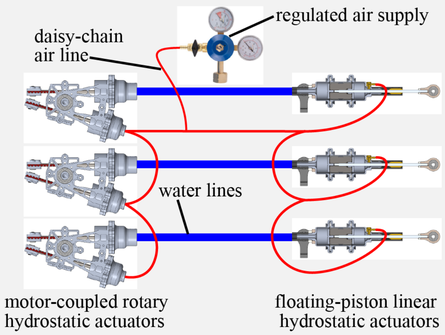
PI meeting video presentation: https://youtu.be/aJbnspOcWgs BGN: https://sites.google.com/view/bgn-pomdp/home

**Challenges:**

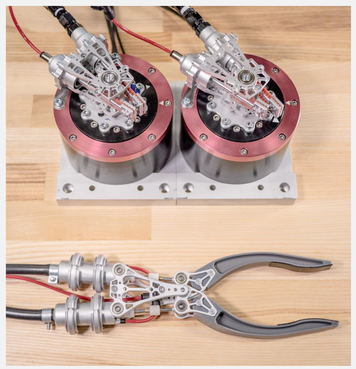
- Building a lightweight arm capable of active high-bandwidth impedance control is hard
- Controlling contact-rich interactions in uncertain environments is hard

**Aims**

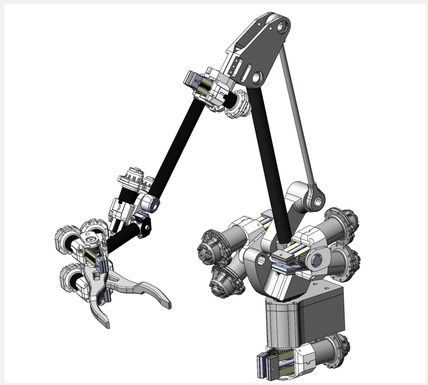
- Developing a lightweight, low-impedence 7-DOF robot manipulator for research and mass production
- Employ ***remote direct drive*** (RDD) actuation concept
- Developing process for learning optimal controllers rather than tuning controllers for specific hardware



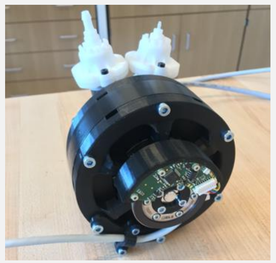

Low-friction hydrostatic transmission

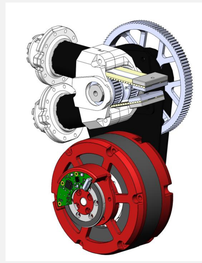


2-DOF gripper, driven by remote direct-drive brushless motors



Under devel. 7-DOF arm, fully remotely actuated





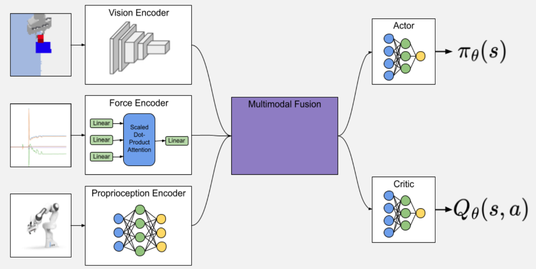
Brushless motor direct-drive and 3:1 coupling to hydraulic transmission rotary actuators

**Equivariant Multimodal Fusion - EMF**

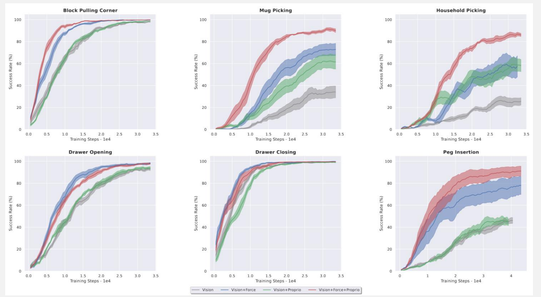
**Goal:** Efficiently fuse multiple heterogenous data modalities into a single joint representation for use in policy learning for contact-rich manipulation

**Aims:**

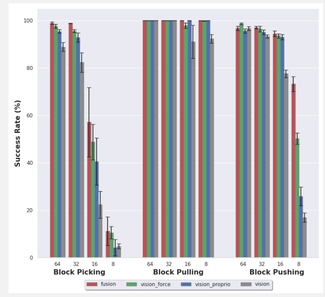
- Expand Equivariant SAC to exploit the joint visual-force SO(2) symmetries
- Quantify the effectiveness of different data modalities in contact-rich manipulation
- Learn manipulation policies directly on physical robot




**EMF combines visual, force, and proprioceptive data using domain-specific equivariant encoders**

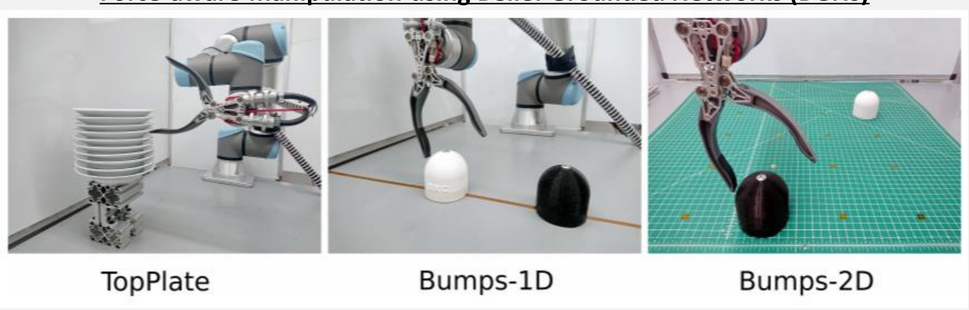



**Sensor Modality Ablation**



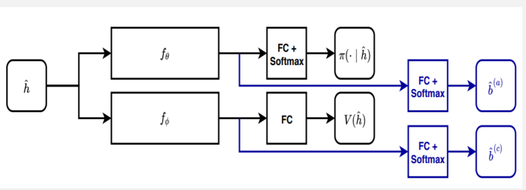

**Reduced Visual Acuity**

**Force-aware manipulation using Belief Grounded Networks (BGNs)**




Manipulation tasks trained on force-feedback from low-impedance fingers

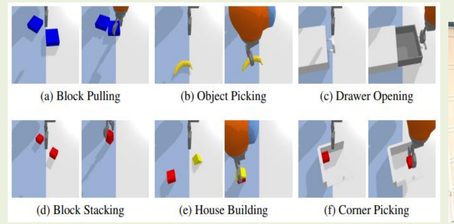
3 different tasks, all training offline




BGN combined with A2C. The belief state is reconstructed from partial observations during training. The resulting policy is history, not belief based, so we forego calculating belief state during runtime.

**Ongoing Work:**

- Online training via teleop demonstrations, leveraging SO(2) Equivariant SAC
- Extend to use the operator-controlled contact impedance in online training




Teleop setup with haptic glove