



Force Feedback Leader Arm for High Quality Demo Data using F/T Sensor

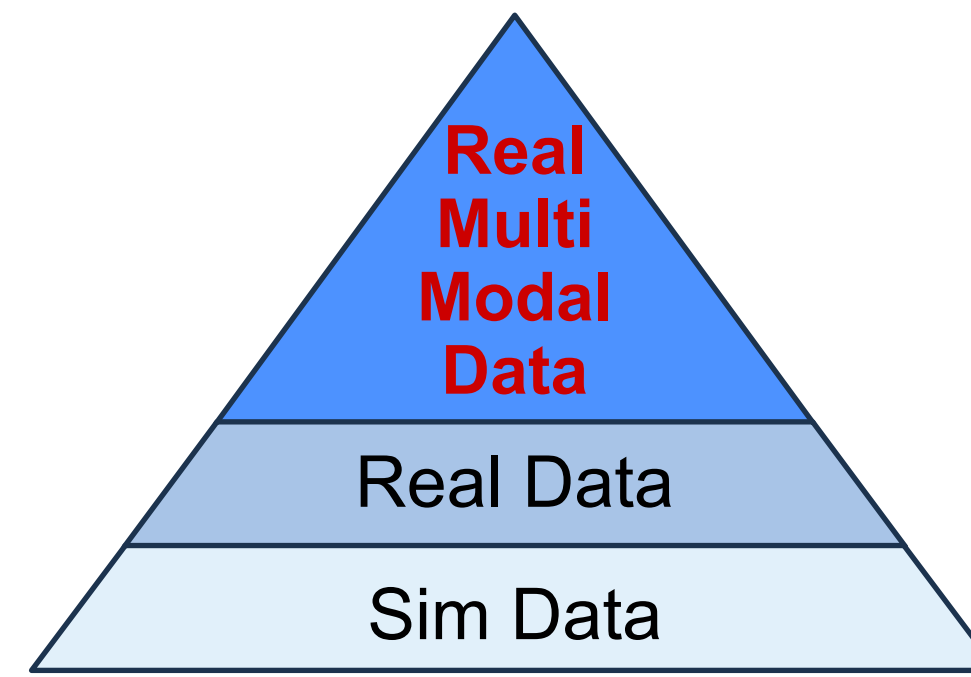
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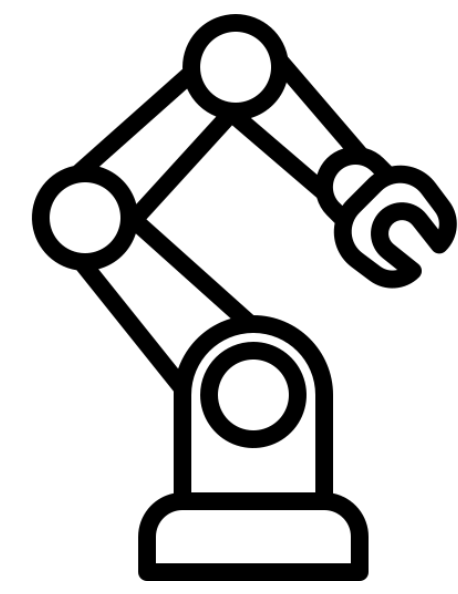
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Introduction

- **Why do we need high quality demo data?**
 - Demo data quality = Imitation learning output (Action)
 - Vision sensors have inherent limitations
 - Lack of physical interaction data



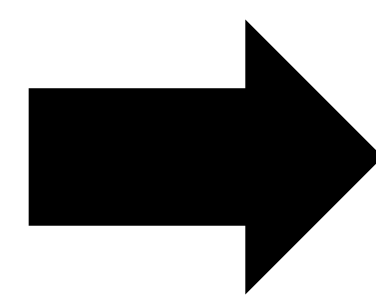
Higher Quality Data



Higher Quality Action

Explain & Results

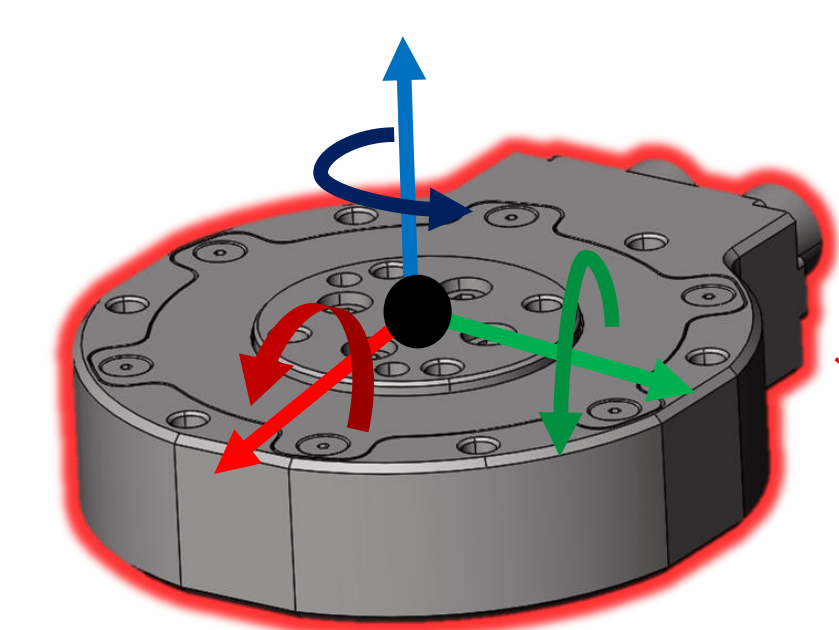
- **Force Feedback via F/T sensor**
 - $\tau_{Feedback} = k_f(J^T F_{ext})$:
Senses contact through leader arm's force feedback
- **Gravity Compensation**
 - $\tau_{Gravity} = k_g(J^T F_{gravity})$:
Compensates for the leader arm's self-weight
- **Teleoperation**
 - Leader current joint angles = Follower target joint angles
 - Teleoperation w/ feedback and gravity compensation



Results

1. Faster and easier collection of **high-quality demo data**
2. More **intuitive** and immersive manipulation
3. Utilization of **force data for training**
4. Precise control
5. System **scalability** & cost reduction

<F/T sensor>

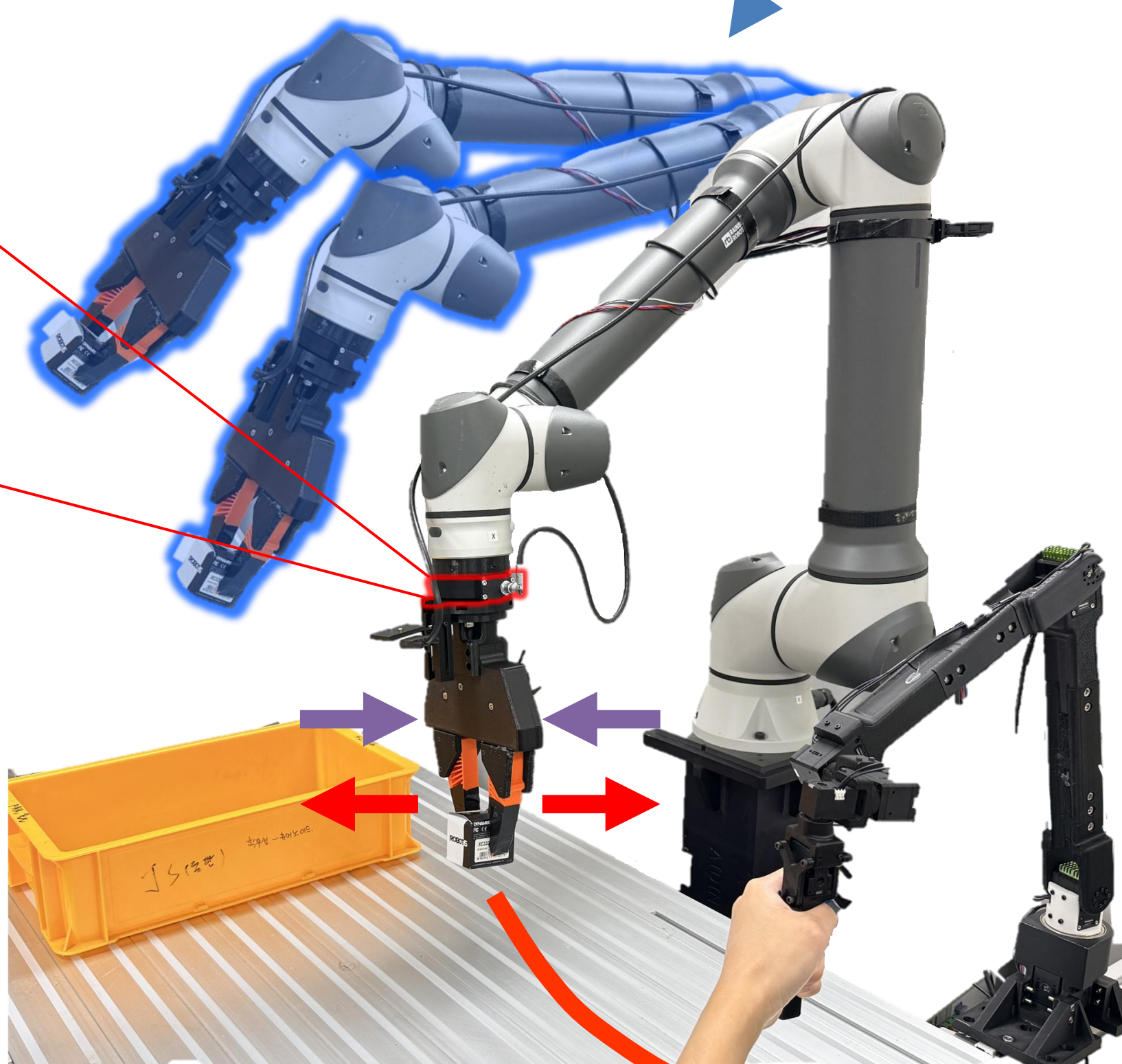


$F_x, F_y, F_z,$
 M_x, M_y, M_z

— Contact

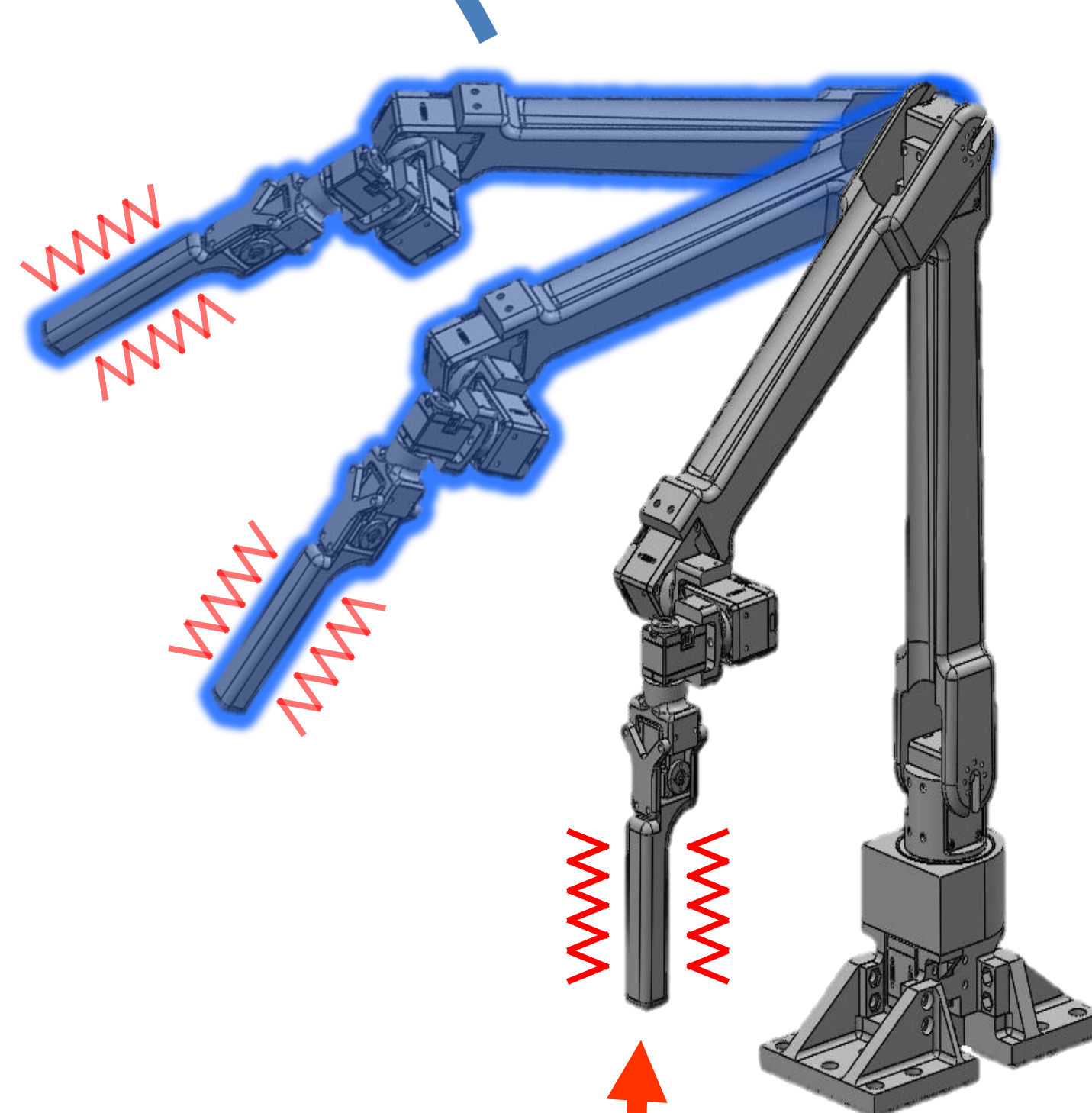
— Force Feedback

<Follower>



Teleoperation

<Leader>



Force Feedback

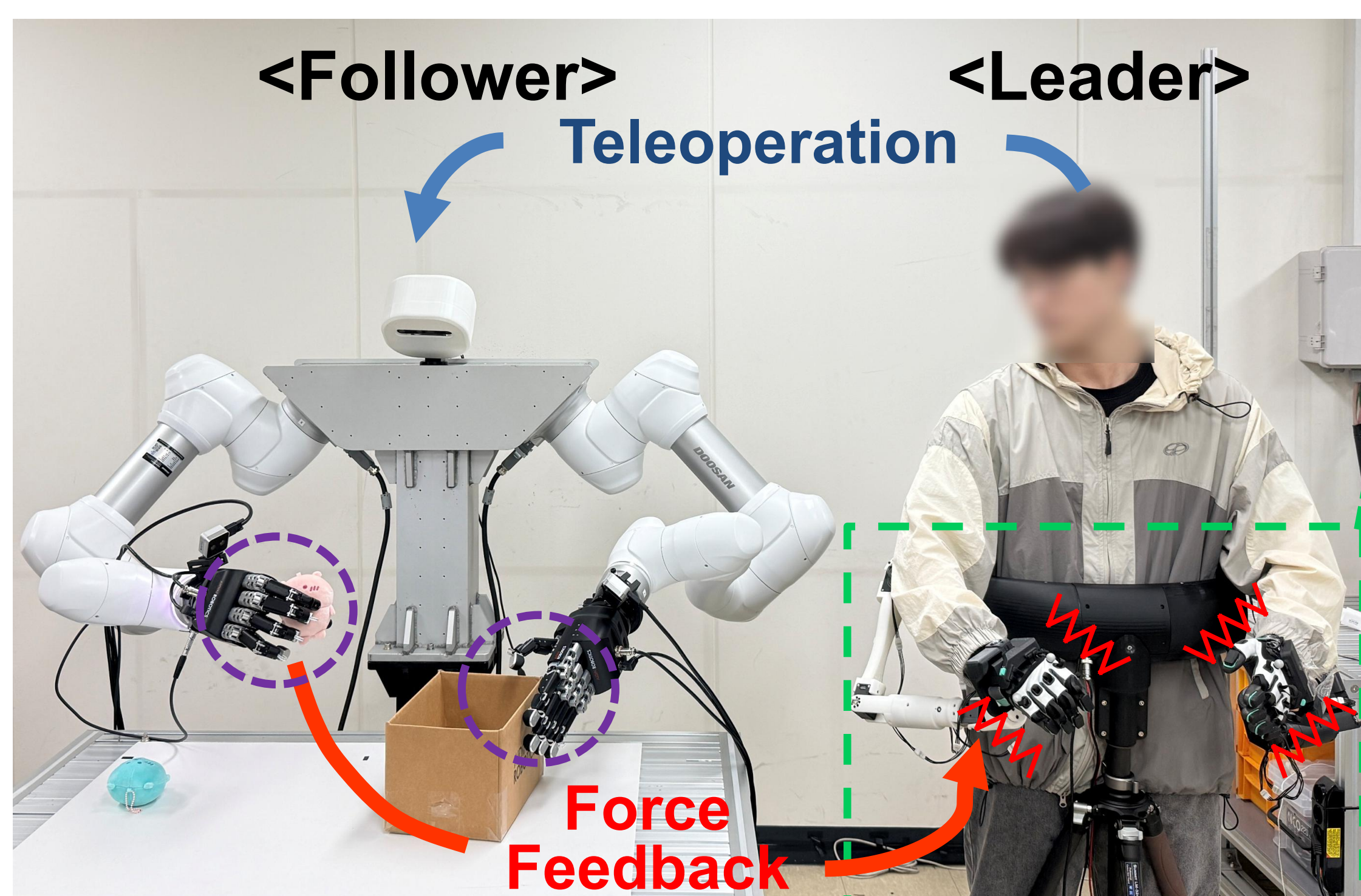
Leader - Follower System & Force Feedback

Functions

1. **Force Feedback**
enabled on all joints
(Follower → Leader)
2. **Gravity compensation**
enabled on all joints
3. **Teleoperation**
(Leader → Follower)

Applications

- **Modulization**
 - Force feedback and data acquisition can be implemented without altering the existing setup, simply by adding an F/T sensor.
 - Easily scalable & Easy to set the system.



Dual arm Leader - Follower system



Dual arm Leader arm

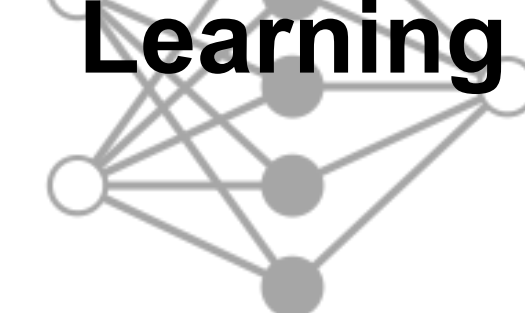
- **Multimodal Imitation Learning**

- Force data can be used to train the policy
- Learn policy from high-quality demos
- Learn policy with contact-awareness

Observation

- Images
- Joint angles
- Force & Moment

Imitation Learning



Action

- Joint angles
- Wrench

