Education

INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY HYDERABAD

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Projects

CARTIN

SCHAEFFLER

DELTA

Volunteering

NTU WORLD OF WISDOM

MAE GRADUATE STUDENT CLUB

swe Society of Women Engineers Nanyang Technological University

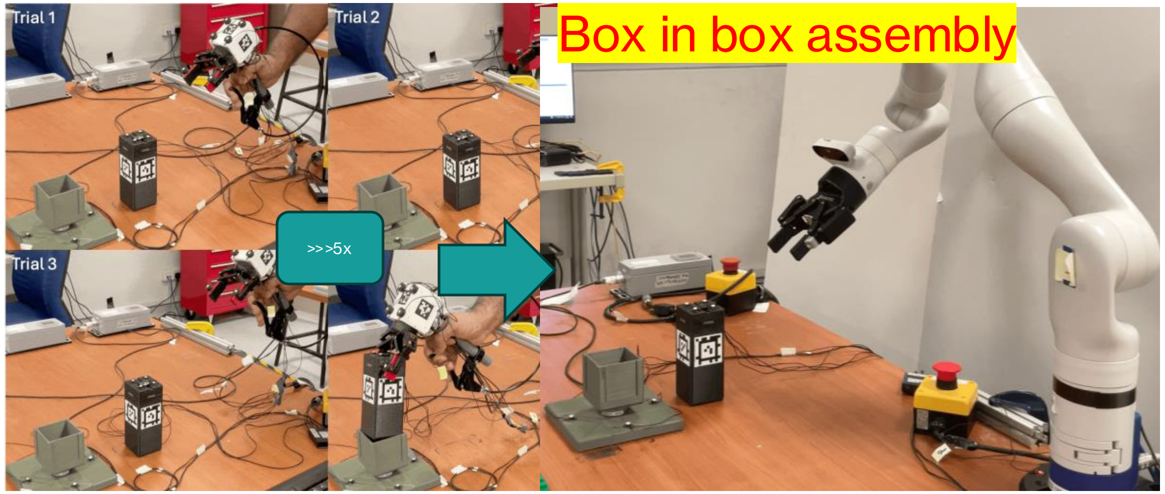
TEDx NTU x = independently organized TED event

POWERS

Sri Harsha Turlapati

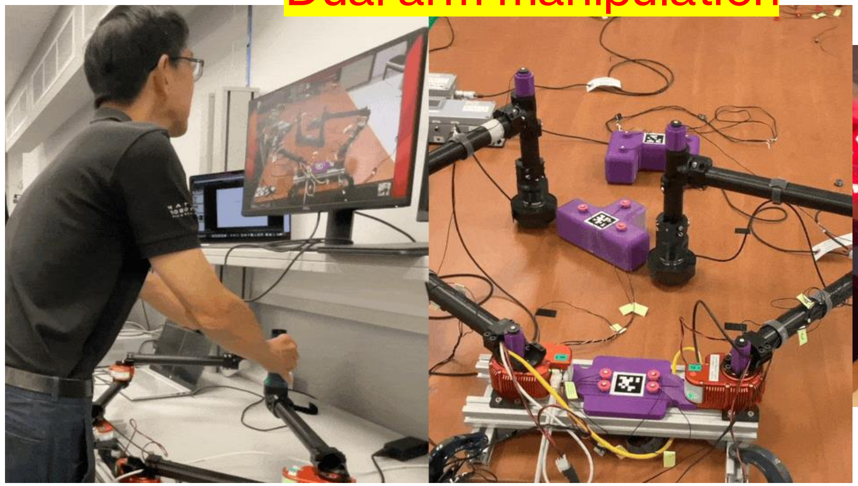
Research Fellow, NTU

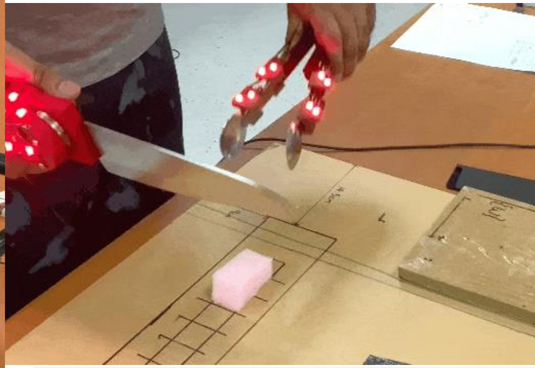
Learning from human (haptic) demonstrations



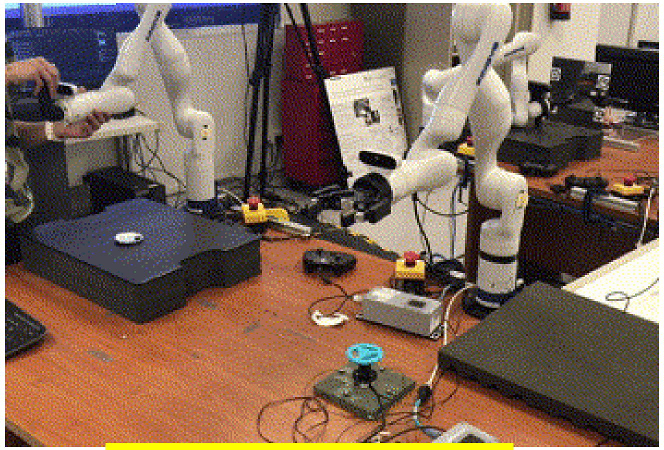
Box in box assembly

Dual arm manipulation



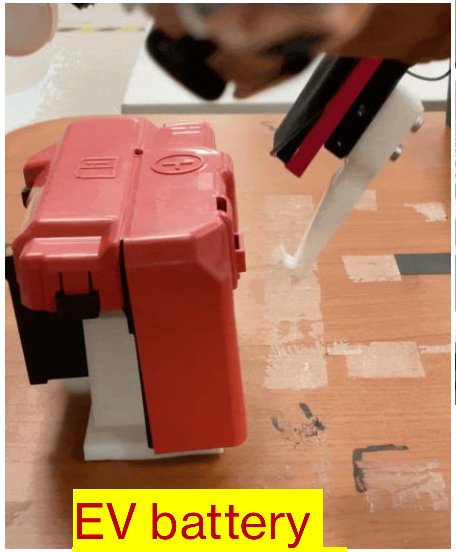


Towards robot kitchen

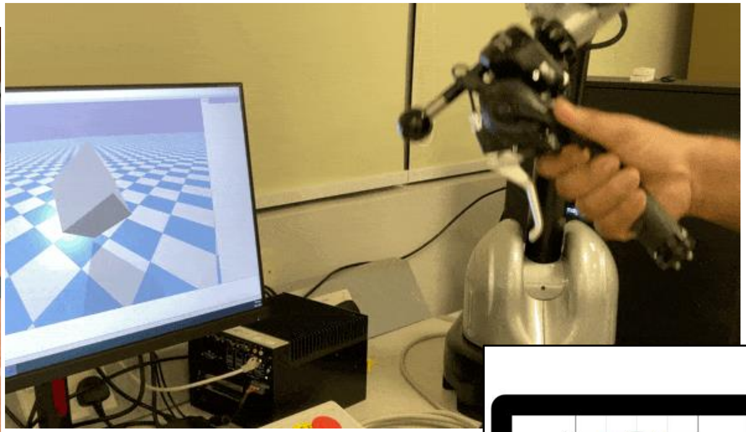


Valve turning with axial misalignment

Wheel bearing inspection

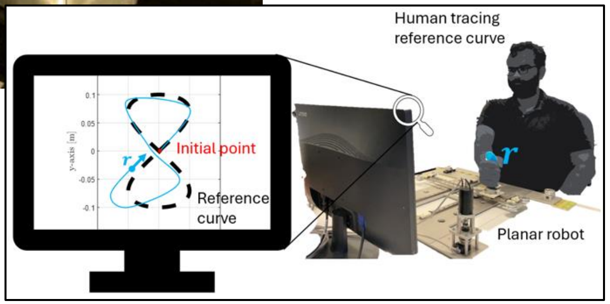


EV battery disassembly



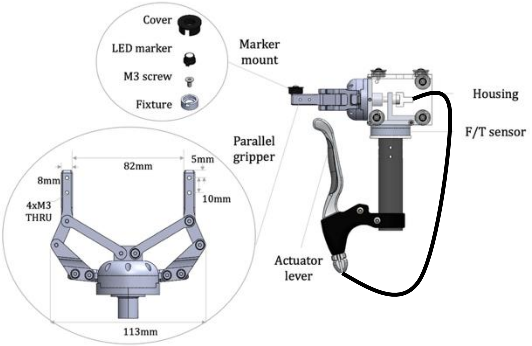
Mixed2real frameworks

Movement synthesis



M1: SENSORIZED GRIPPER

Built using off the shelf parts



Turlapati, Sri Harsha, Gautami Golani, Mohammad Zaidi Ariffin, and Domenico Campolo. "Sensorized gripper for human demonstrations." *arXiv preprint arXiv:2503.14855*(2025).

Anybody can program a robot

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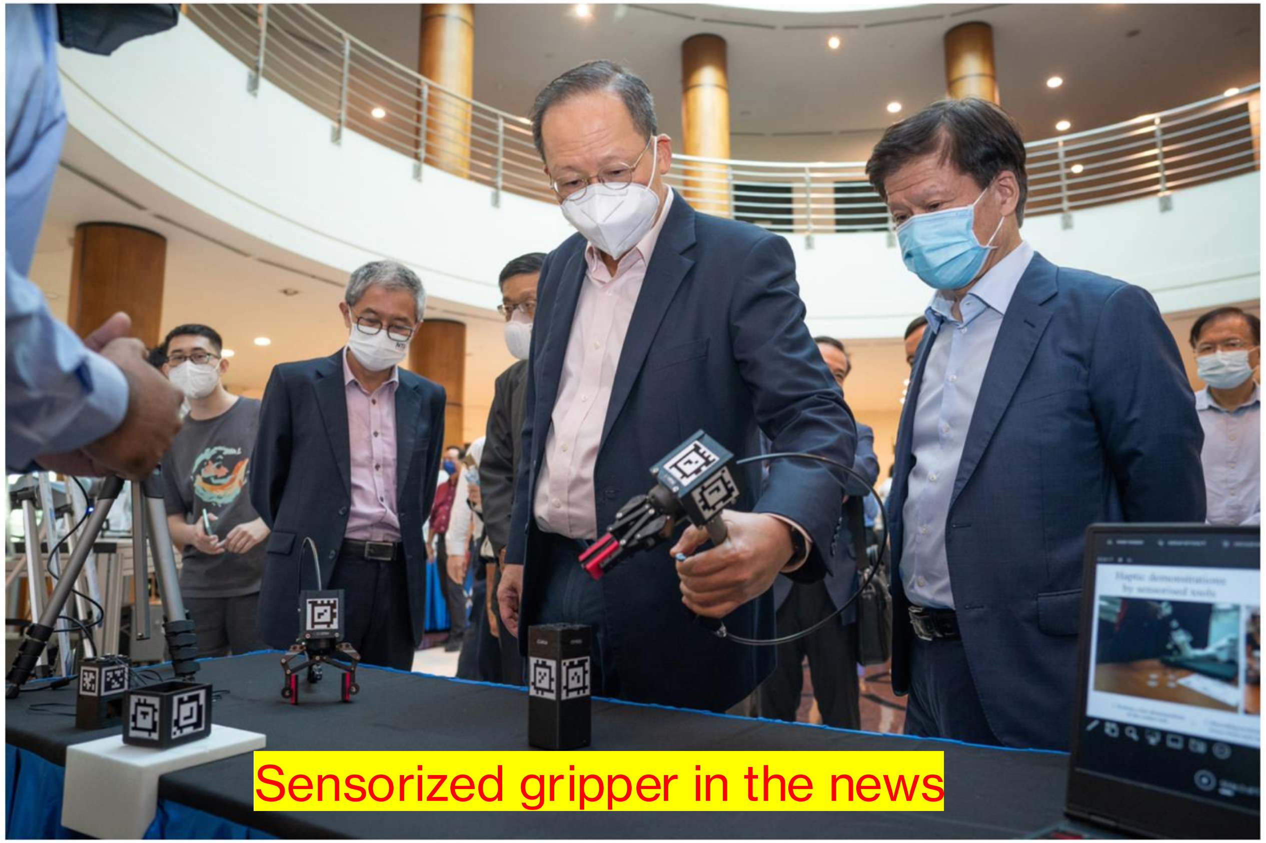
CARTIN

https://www.straitstimes.com/singapore/consumer/new-research-centre-in-ntu-to-further-drive-robotics-role-in-spores-development

New research centre in NTU to further drive robotics' role in S'pore's development



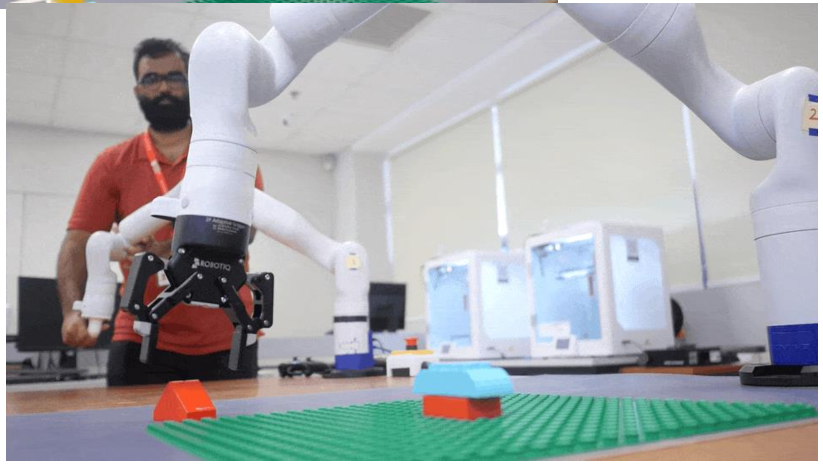
Sensorized gripper in the news

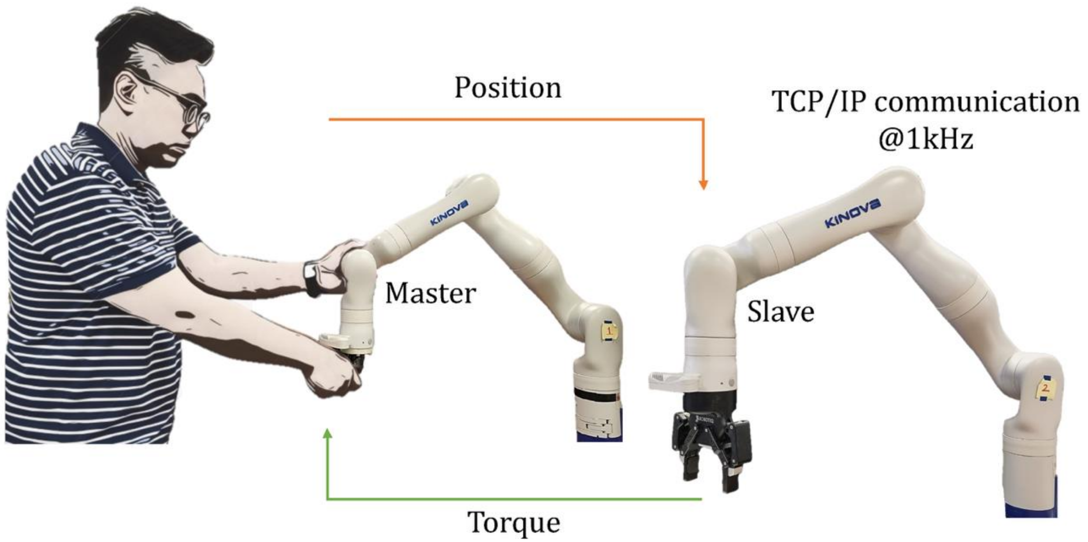
Manpower Minister Tan See Leng (centre) at a demonstration booth during the launch of the new research facility. ST PHOTO: SYAMIL SAPARI

M2: TELEOPERATED ROBOTS

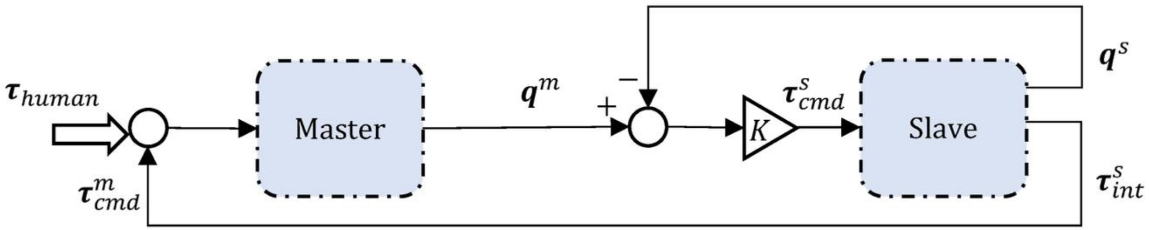
Kana, Sreekanth, Juhi Gurnani, Vishal Ramanathan, Mohammad Zaidi Ariffin, **Sri Harsha Turlapati**, and Domenico Campolo. "Learning compliant box-in-box insertion through haptic-based robotic teleoperation." *Sensors* 23, no. 21 (2023): 8721.

Jeffrey Williams
(NASA Astronaut)





(**a**) Human user operating the master–slave teleoperated system.



(**b**) Teleoperation control block diagram.

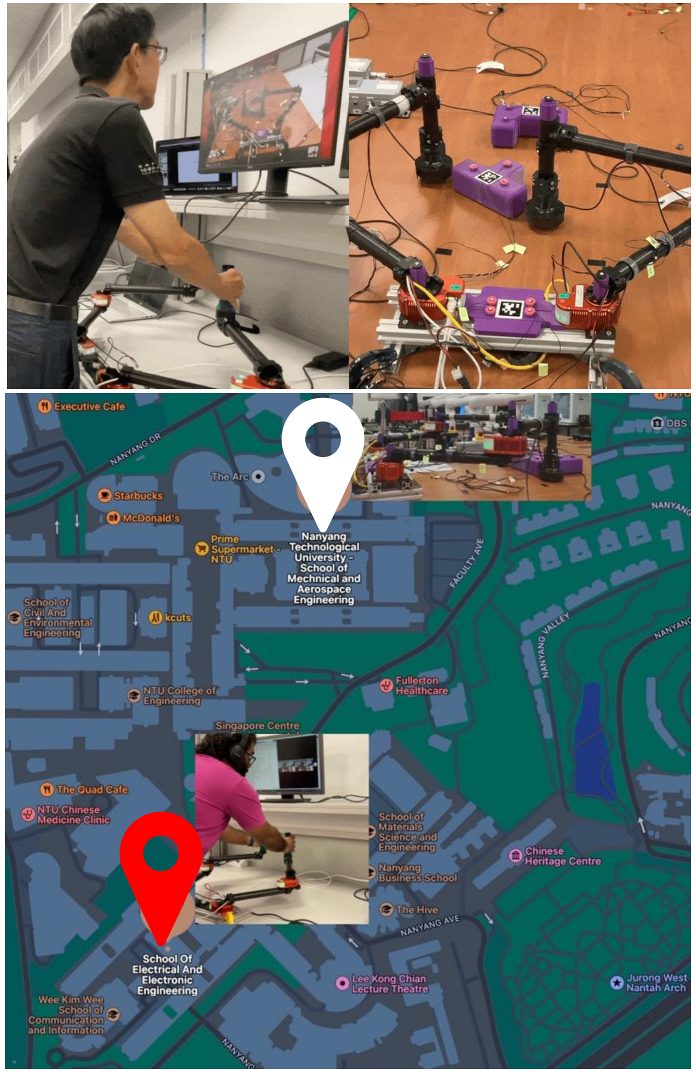
ON HAPTIC SENSING

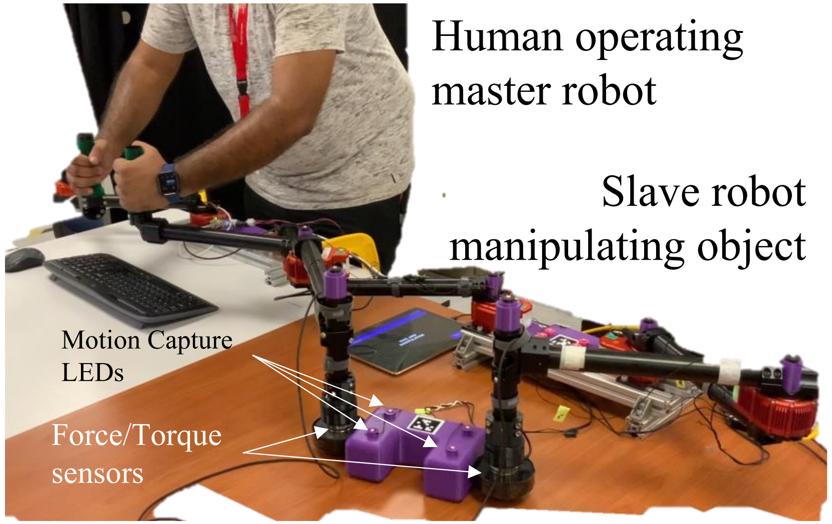
How can you use haptic sensors on the robot hands, and joints to infer task state?

Planar dual arm manipulation

Turlapati, Sri Harsha, and Domenico Campolo. "Towards haptic-based dual-arm manipulation." *Sensors* 23, no. 1 (2022): 376.

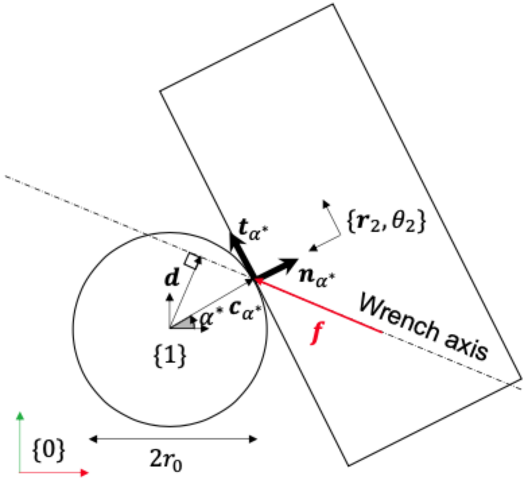
Remote teleoperation

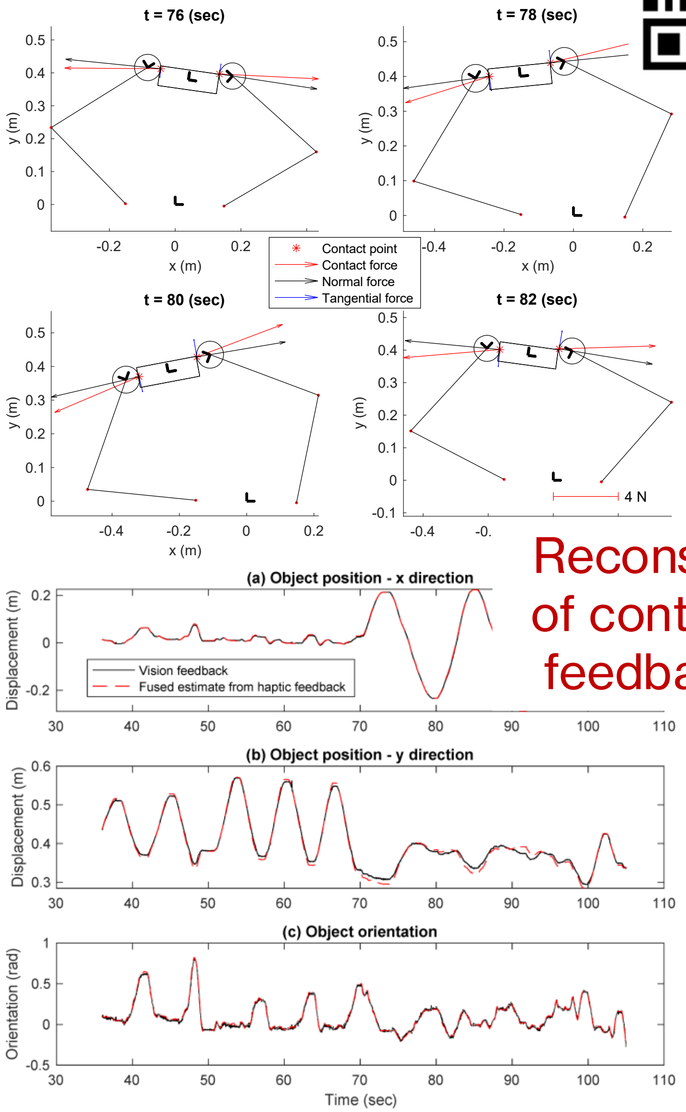




Human demonstration of manipulation task

Contact estimation from force measurement



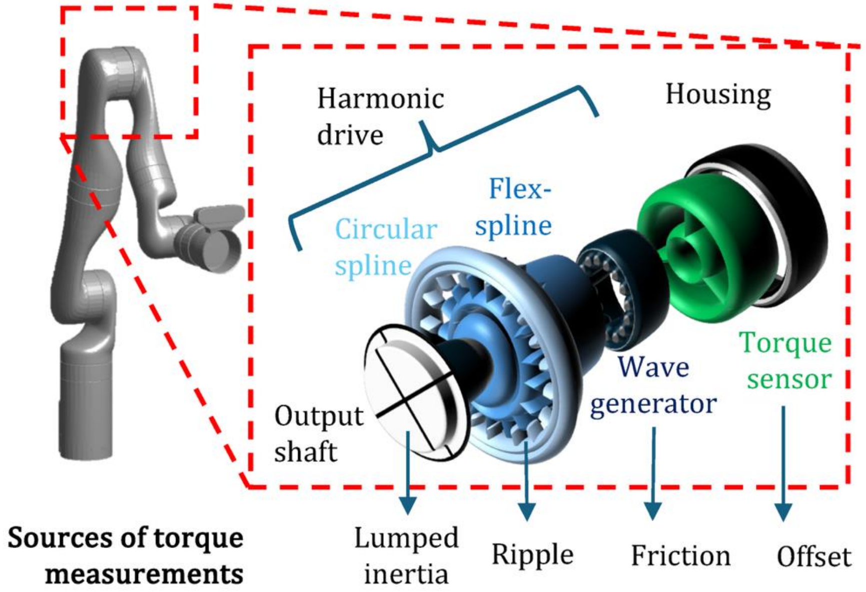


Reconstruction of contact from feedback data

Torque sensed at every joint is a sum of intrinsic dynamics

Sensed torque → $\tau = \tau_f + \tau_i + \tau_r + \tau_o$

	Friction	Inertia	Ripple due to gear	Torque sensor offset
Depends on	Joint velocity $\dot{\boldsymbol{q}}$	Joint acceleration $\ddot{\boldsymbol{q}}$	Joint position $\boldsymbol{q}$	Sensor bias



We model the sensed torque as a function of joint position, velocity and acceleration

$$\boldsymbol{\tau}_{robot} = \boldsymbol{\Phi}(\boldsymbol{q}, \dot{\boldsymbol{q}}, \ddot{\boldsymbol{q}})\boldsymbol{w}$$

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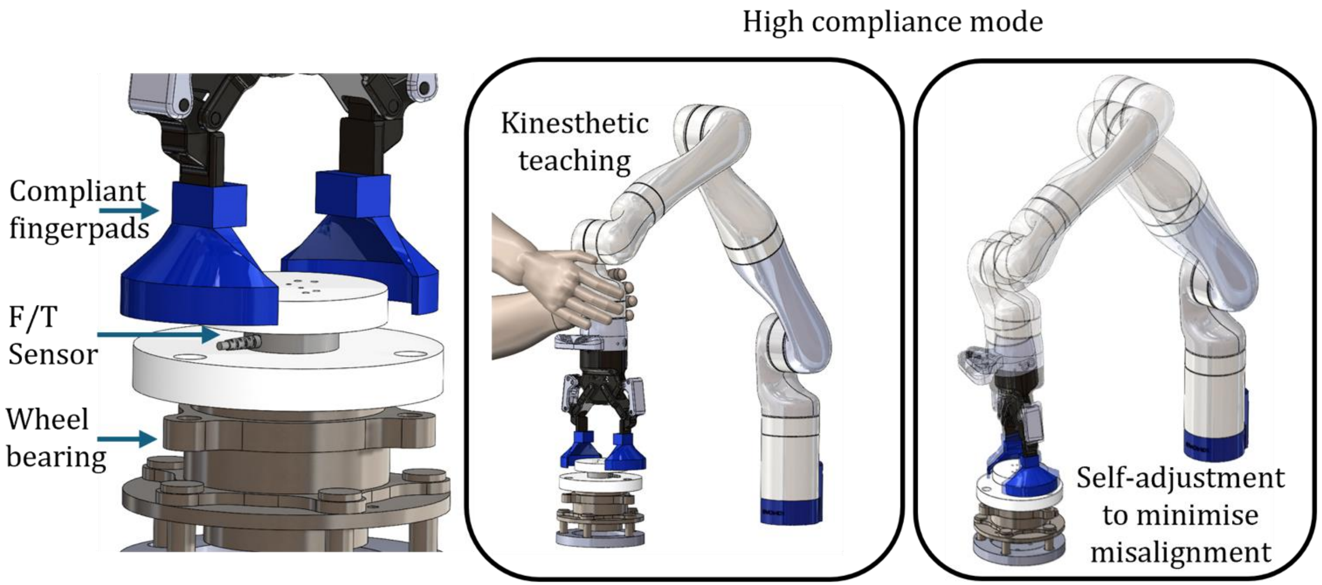
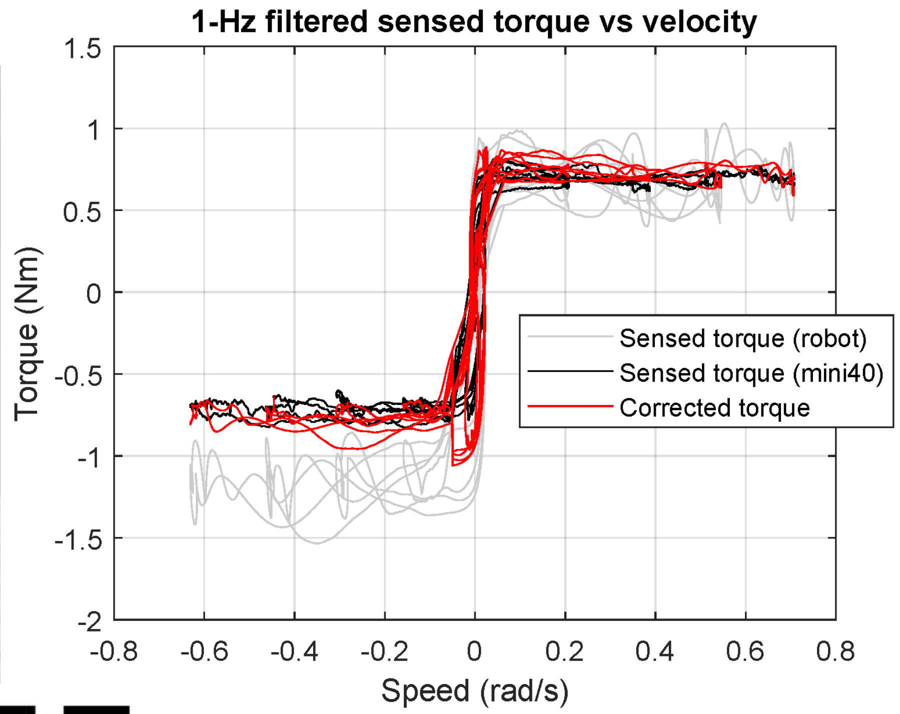
Wheel bearing turning with intrinsic dynamic compensation





Turlapati, Sri Harsha, Juhi Gurnani, Mohammad Zaidi Bin Ariffin, Sreekanth Kana, Alvin Hong Yee Wong, Boon Siew Han, and Domenico Campolo. "Identification of Intrinsic Friction and Torque Ripple for a Robotic Joint with Integrated Torque Sensors with Application to Wheel-Bearing Characterization." *Sensors (Basel, Switzerland)* 24, no. 23 (2024): 7465.

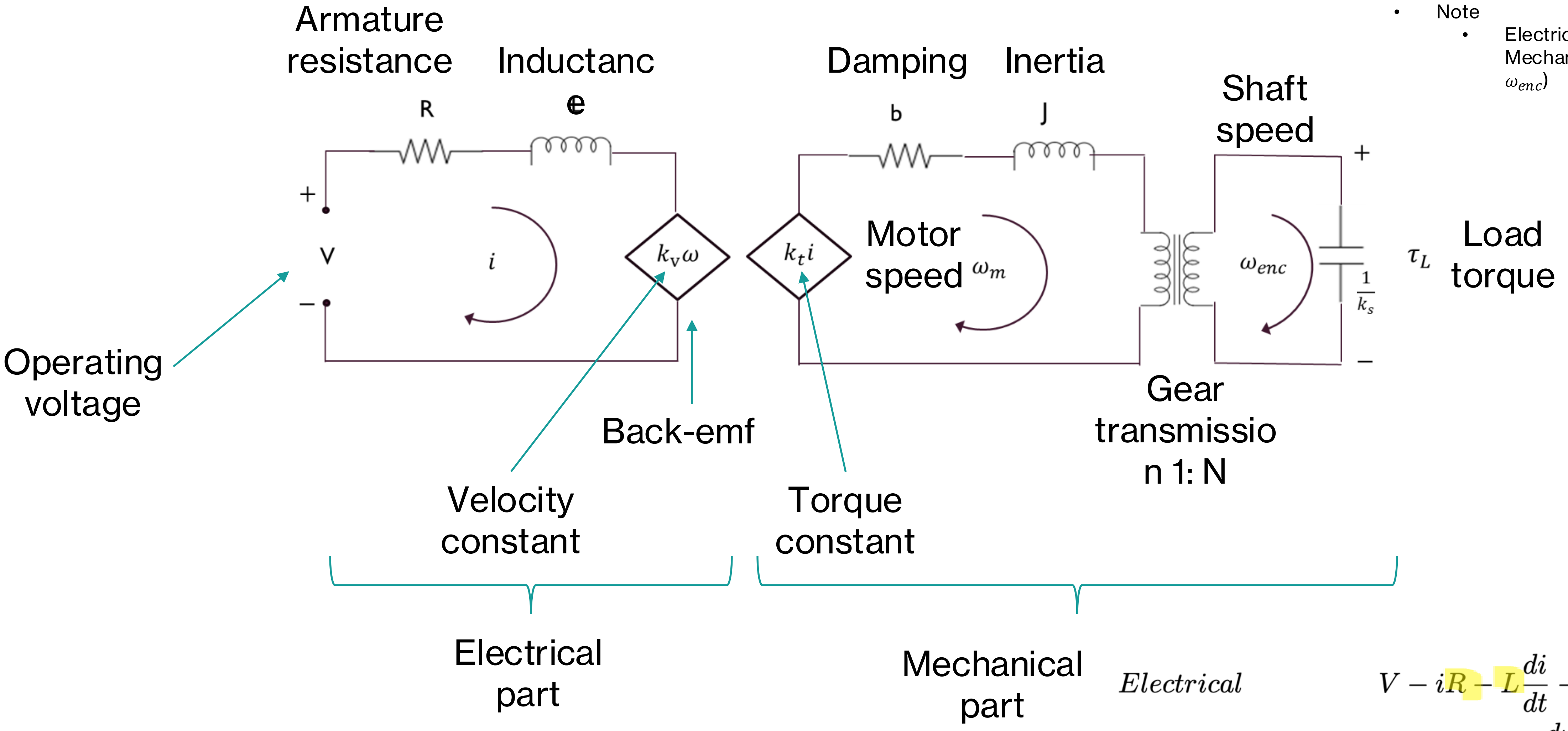
Read more here

ROBOTICS EDUCATION: FROM DATA TO MODELS

This content was part of a lecture series in MA2011 : Mechatronic Systems and Interfacing

Electromechanical model of SEA

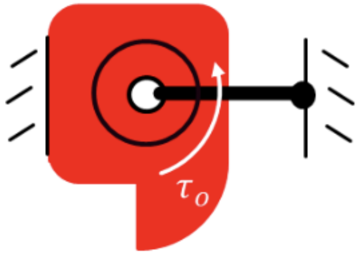
- If
  - voltage ~ torque
  - current ~ speed
- Then
  - Inductance ~ inertia
  - Resistor ~ damping
  - Capacitor ~ compliance
- Note
  - Electrical power (V*i) ~ Mechanical power ($\tau_L * \omega_{enc}$)



$$Electrical \qquad V - iR - L\frac{di}{dt} - k_V\omega_{enc} = 0$$

$$Mechanical \qquad k_t i - b\omega_m - J\frac{d\omega_m}{dt} - \frac{\tau_L}{N} = 0$$

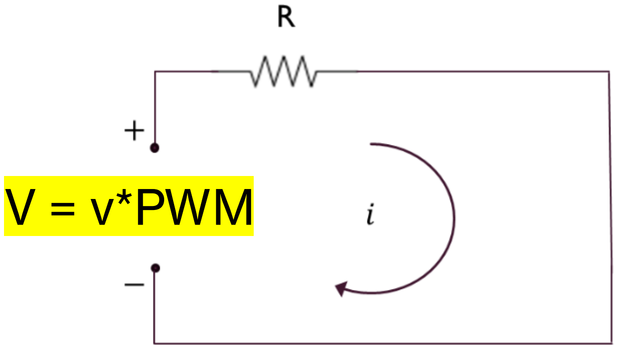
Stall test



$$V - iR - L\frac{di}{dt} - k_V\omega_{enc} = 0$$

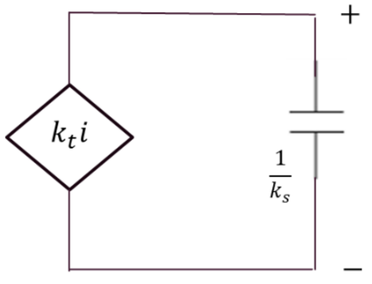
$$k_t i - b\omega_m - J\frac{d\omega_m}{dt} - \frac{\tau_L}{N} = 0$$

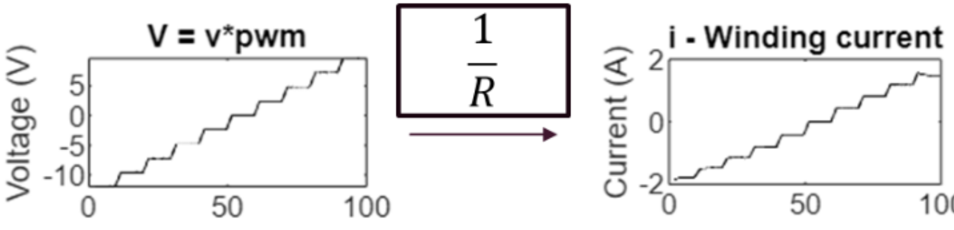
Command: Varying PWM

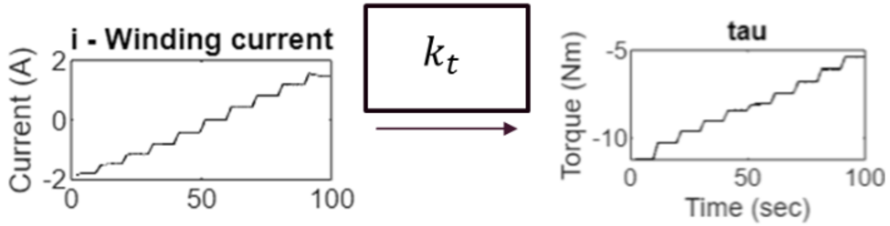


Armature resistance

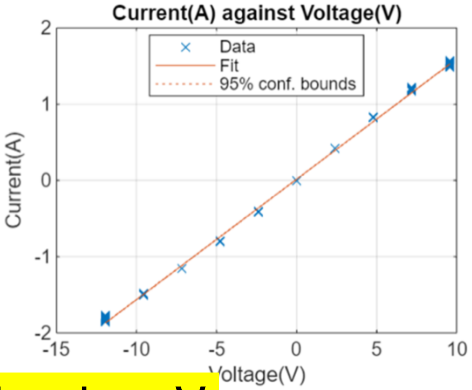
Torque constant







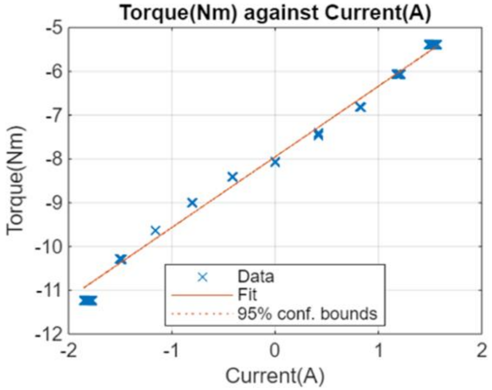
Trials	Resistance Ω	R square	standard deviation Ω	Relative error (%)
1	6.3457	0.998	0.342	5.39%
2	6.3131	0.998	0.344	5.45%
3	6.3205	0.997	0.349	5.52%
4	6.3117	0.998	0.348	5.51%
5	6.3159	0.998	0.345	5.46%



Data points taken only when V was constant, i.e., no transients

Trials	Torque Constant (Nm\A)	R^2	Standard deviation (Nm\A)	Relative standard error (%)
1	1.6357	0.987	0.1207	7.38%
2	1.6353	0.987	0.1238	7.57%
3	1.6388	0.987	0.1221	7.45%
4	1.6423	0.986	0.1253	7.63%
5	1.6354	0.988	0.1209	7.39%

a

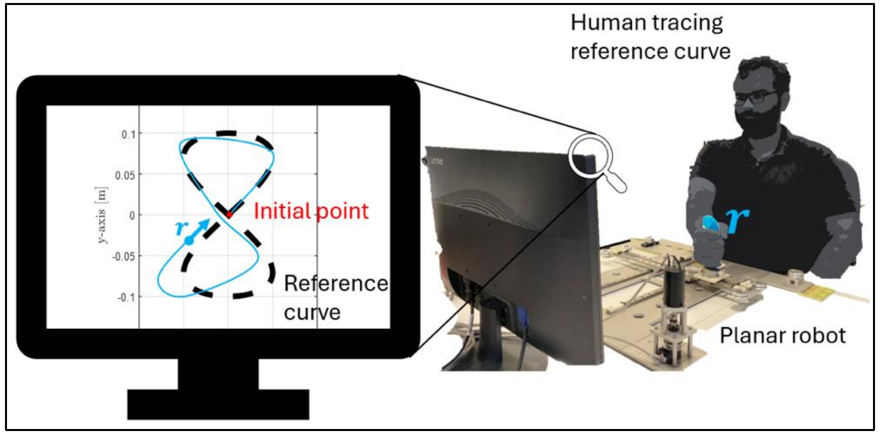


b

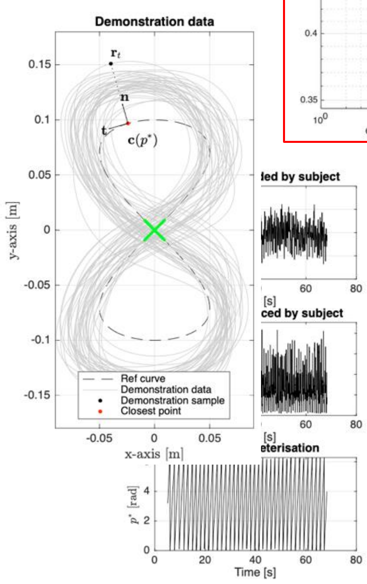
MOVEMENT SYNTHESIS

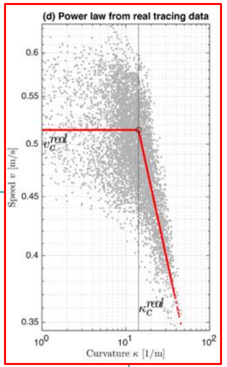
I’m also very interested in studying human behavior, but with the aim of reusing discovered strategies in robot *movement synthesis*

GEOMETRIC INVARIANT LEARNING : LEARNING HUMAN STYLE



Human demonstration of tracing task

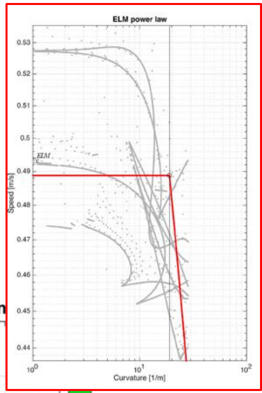


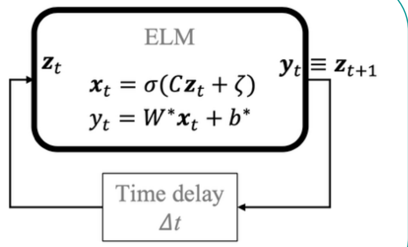


Filtering raw data

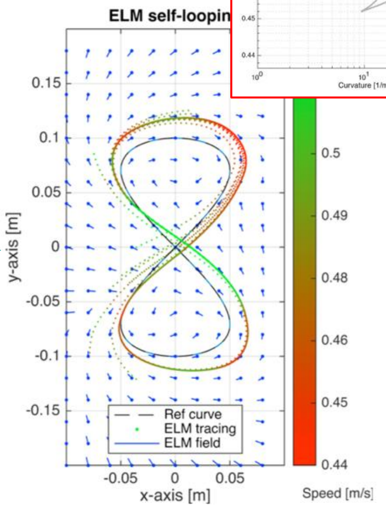
Human generated power law

Machine generated tracing





Training machine



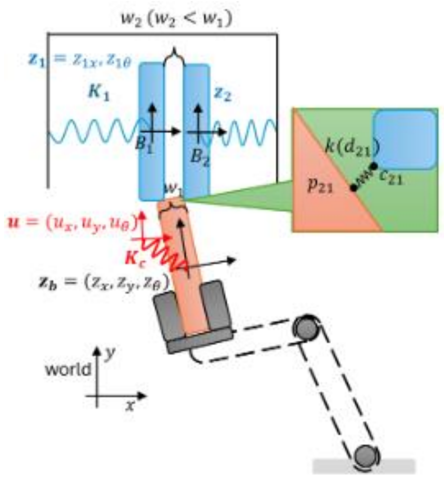
Turlapati, Sri Harsha, Lyudmila Grigoryeva, Juan-Pablo Ortega, and Domenico Campolo. "Tracing curves in the plane: Geometric-invariant learning from human demonstrations." *PloS one* 19, no. 2 (2024): e0294046.

OPTIMAL ROBOT CONTROL

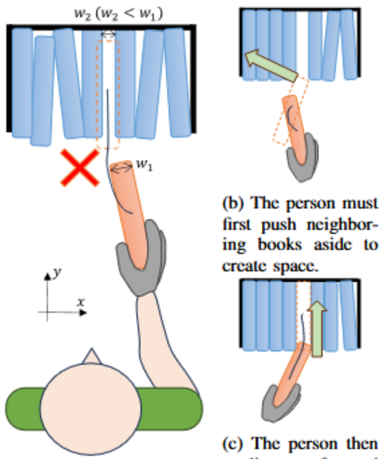
Key idea – Use haptic costs to perform trajectory optimization.

Manipulation planning

Pushing aside neighbouring books is needed in a crowded bookshelf



Modelling the bookshelf as a planar elastic world

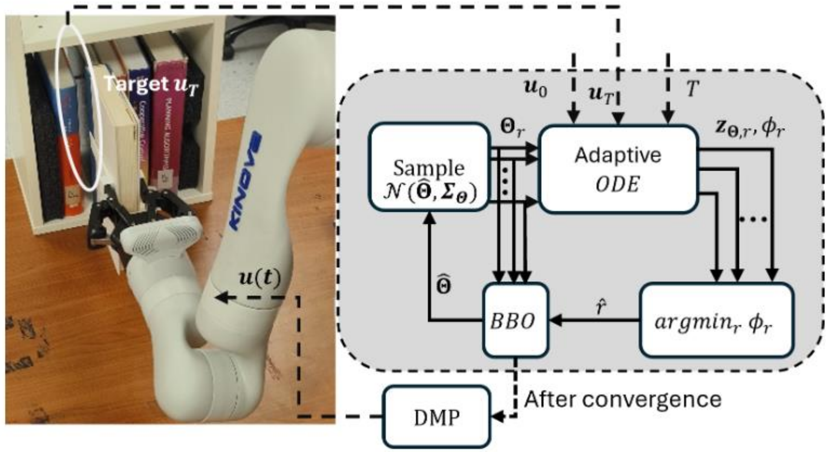


(a) A traditional planner fails to place the book due to limited space.

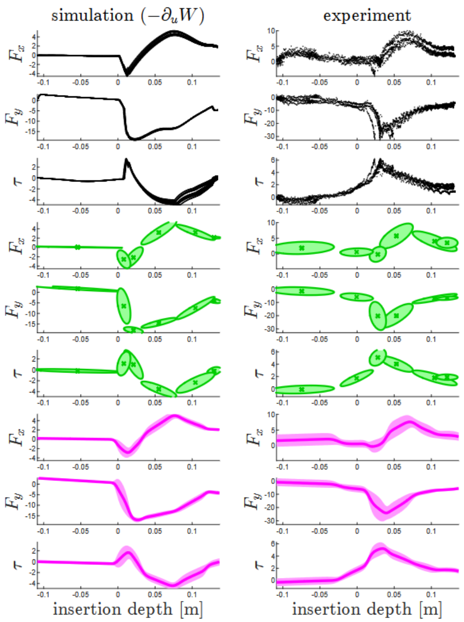
(b) The person must first push neighboring books aside to create space.

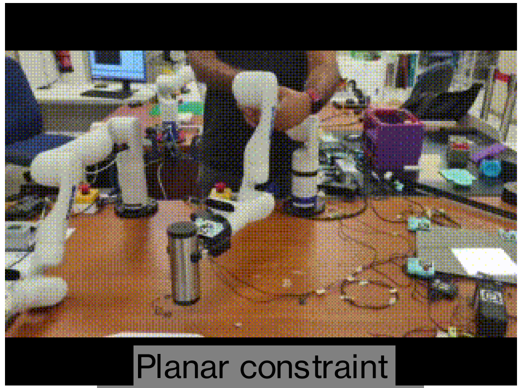
(c) The person then applies a forward force to slide the book into the shelf.

Yang, Lin, **Sri Harsha Turlapati**, Chen Lv, and Domenico Campolo. "Planning for Quasi-Static Manipulation Tasks Via an Intrinsic Haptic metric: A Book Insertion Case Study." *IEEE Robotics and Automation Letters* (2025).

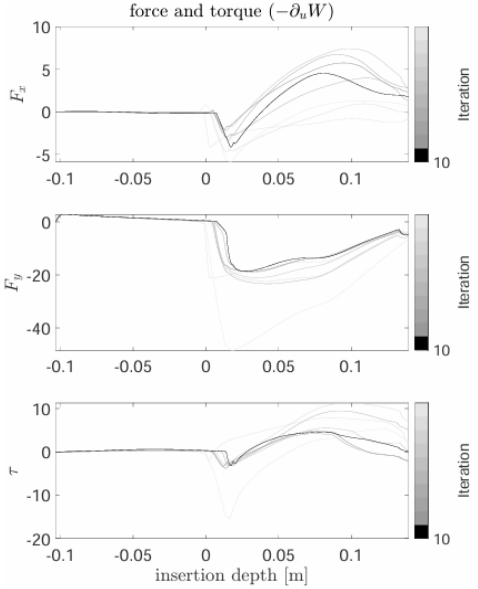


Simulation v.s. real world





Planar constraint implemented on robot

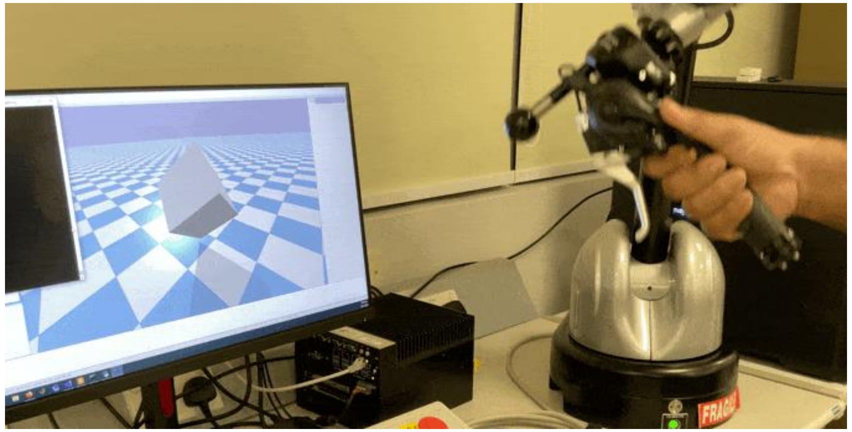


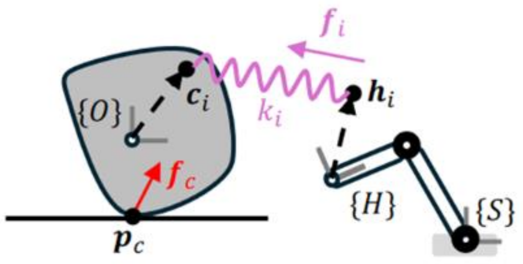
Optimal control force in each iteration

MIXED2REAL FRAMEWORKS

Rather than producing data from real world experiments, instead get humans to interact with a virtual world with haptic feedback to produce similarly useful data, without the risk of damage, high expenditure.

Testing slipping of cube corner on plane





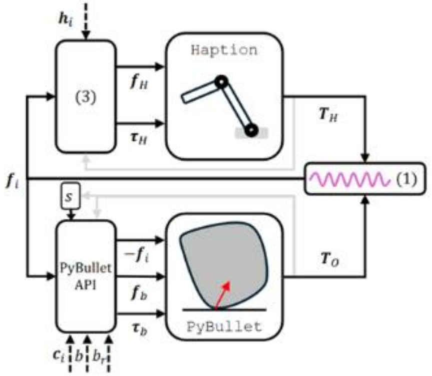


Figure 1: Mechanical interaction rendering.

$$f_i = k_i(T_O \circ \tilde{c}_i - T_H \circ \tilde{h}_i)$$

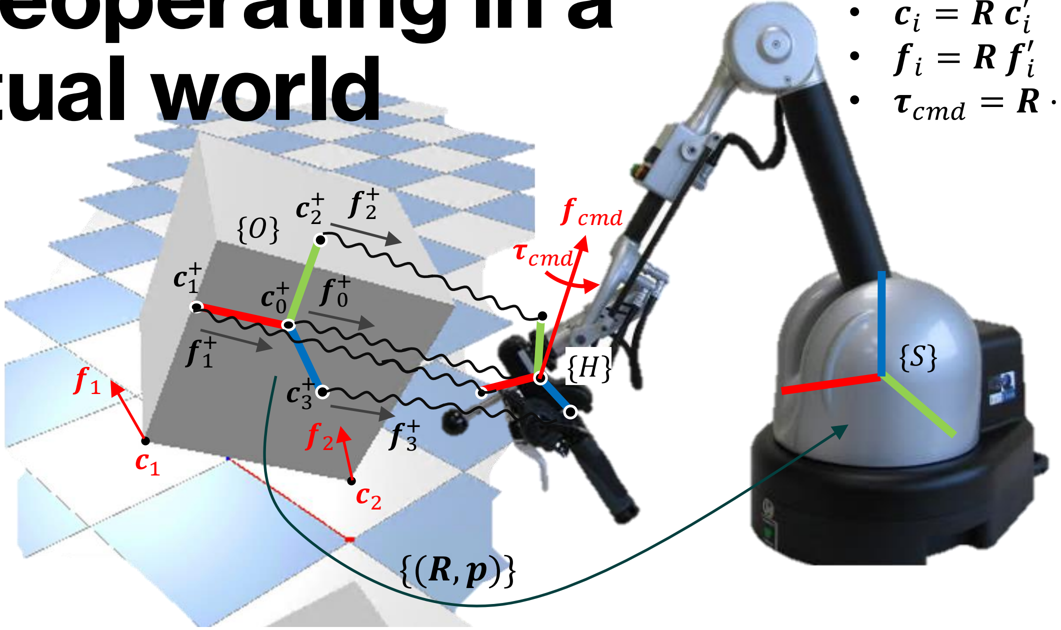
$$T \circ \tilde{v} := \begin{bmatrix} \mathbb{I}_3 & 0 \end{bmatrix} T \begin{bmatrix} \tilde{v}^T & 1 \end{bmatrix}^T$$

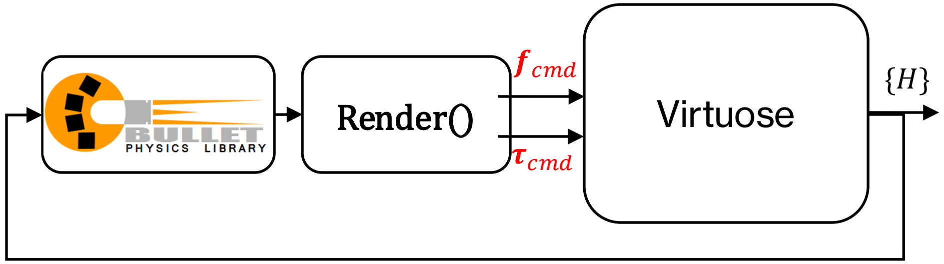
$$W_H = \begin{bmatrix} f_H \\ \tau_H \end{bmatrix} = \sum_i \begin{bmatrix} f_i \\ (h_i - p_H) \times f_i \end{bmatrix}$$

Mixed2Real frameworks : Teleoperating in a virtual world

Render()

- $f_{cmd} = \Sigma_i f_i$
- $c_i = R\, c_i'$
- $f_i = R\, f_i'$
- $\tau_{cmd} = R \cdot (\Sigma_i [c_i']_\times f_i')$





THANKS TO ALL MY COLLABORATORS!