CoRL 2025 Demo/Exhibition Proposal :
FreeTacMan: Robot-free Visuo-Tactile Data Collection System for Contact-rich Manipulation

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Abstract:

Enabling robots with **contact-rich manipulation** remains a pivotal challenge in robot learning, which is substantially hindered by the **data collection gap**, including its inefficiency and limited sensor setup. Traditional teleoperation systems[1-5] offer **no** direct**,** real-time tactile signals, and impose fixed robot setup with complex calibration or high latency. While prior work has explored handheld paradigms[6], their rod-based mechanical structures remain rigid and unintuitive, providing limited tactile feedback and posing challenges for human operators.

Motivated by the dexterity and force feedback of human motion, we propose **FreeTacMan**, a **human-centric** and **robot-free** data collection system for accurate and efficient robot manipulation. Concretely, we design a **wearable** data collection device with dual **visuo-tactile** grippers, which can be worn by human fingers for intuitive and natural control. A high-precision optical tracking system is introduced to capture end-effector poses while synchronizing **visual** and **tactile** feedback. FreeTacMan achieves multiple improvements in data collection performance compared to prior works, and enables effective **policy learning** for contact-rich manipulation tasks with the help of the visuo-tactile information.

Novelty and Relevance to Robot Learning:

Our demo aligns with "systems for data collection". Its two main contributions are:

1. A **compact, low-cost, high-resolution** visuo-tactile sensor (15–20 μm resolution, 358 mm² FoV, 18 mm thickness, USD 30) that easily mounts on diverse end effectors.
2. An **wearable, robot-free** tactile data-collection system that leverages a handheld gripper and the proposed sensor, enabling efficient collection of visuo-tactile demonstrations. Experiments show imitation policies trained with our data **outperform** vision-only policies **by 50 % in success rate** for a range of contact-rich manipulation tasks.

Required Space: Approximately 2 meters in height, 2 meters in length, and 1 meter in width.

Physical Safety: FreeTacMan is lightweight, low-voltage, and passively actuated through human motion, ensuring intuitive control without imposing danger to the operator or nearby observers. During the demonstration, a trained demonstrator will operate the system, and participants will be guided one-on-one to ensure correct and safe usage. Additionally, all cables and equipment will be securely fastened to prevent accidental disconnection.

Hardware: A wearable device with dual fingertip visuo-tactile sensors and a wrist-mounted camera.The device is lightweight (157.5 g) and compact (145 × 85 × 106 mm³), making it portable and user-friendly.

Detailed Description and Visualizations:

Visuo-Tactile Sensor. As shown in Fig. 1(a), our visuo-tactile sensor integrates the sensing module, a compact camera, programmable illumination, acrylic, and deformable gel layer-into a single unit, collectively enabling **high-fidelity** tactile imaging. This module snaps onto the gripper-finger interface via a mechanical connector. Compared to GelSight Mini[7], our sensor offers **higher resolution**, a **larger field of view**, **reduced thickness**, and much **lower cost**.

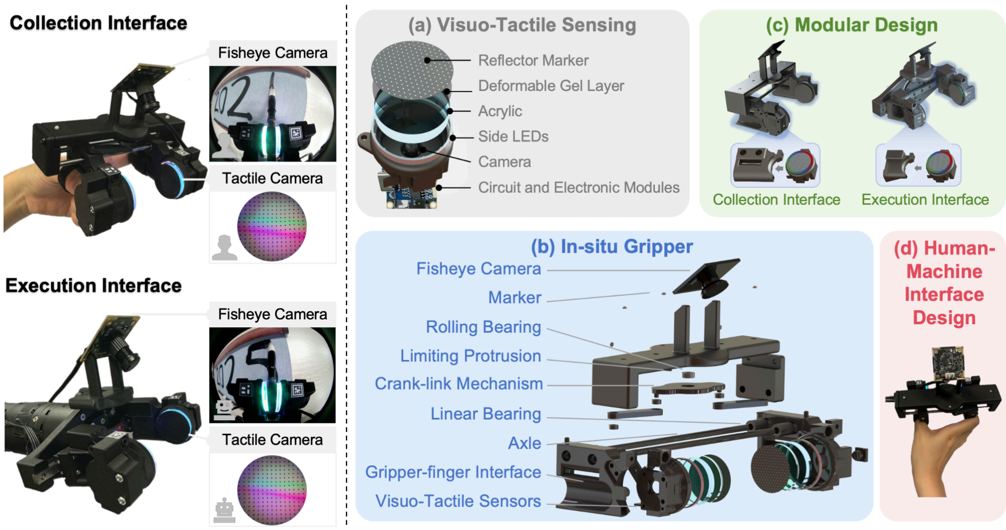

Figure 1: The hardware system of FreeTacMan. *Left:* The wearable gripper in the collection and execution interface respectively, with identical visual and tactile observations. *Right:* (a) Composition of the visuo-tactile sensor. (b) Exploded view of FreeTacMan. (c) The modular design allows for an agile switch between the collection and execution interface. (d)Human-machine interface design.

Wearable Gripper. As shown in Fig. 1(b), FreeTacMan achieves high-precision tactile data collection through the following designs:

- Fingertip-mounted sensors eliminate rods or linkages, providing **direct**, **unattenuated** tactile feedback for the human operator.
- A **High-precision** linear transmission mechanism (chrome-plated shafts + bearings) enforces straight motion with ≤ 0.02 mm axial deviation.
- An inverted crank-slider converts finger motion to **synchronized linear output;** dual shafts with rolling bearings minimize friction, yielding > 90 % transmission efficiency.

Modular Architecture. FreeTacMan system is built as three plug-and-play modules: a sensor perception module for tactile data collection, a universal gripper interface (Fig. 1(c)) for robot compatibility which supports rapid assembly and disassembly of the sensor, and a camera mounting scaffold to ensure stable, aligned visual feedback from wrist camera.

Human-Machine Interface Design. To achieve rapid adaptability, we incorporate **hook-and-loop straps** as a fingertip fastening mechanism, as illustrated in Fig. 1(d). Furthermore, nylon straps offer enhanced breathability and sweat-resistant properties, ensuring user comfort and minimizing the risk of skin irritation during prolonged usage.

Appendix

Brief Biography of the Proposers

Longyan Wu is currently pursuing the Ph.D. degree in Shanghai Innovation Institute and Fudan University, co-advised by Prof. Hongyang Li and Prof. Ran Huang. She has won the National Scholarship multiple times and obtained authorized US patents. Her research interests include tactile sensing and robot manipulation.

Checheng Yu is currently a research intern in Shanghai Innovation Institute advised by Hongyang Li, he received his B.Eng degree from Nanjing University. His research interests include robot manipulation and tactile sensing.

Jieji Ren is currently a postdoc in Shanghai Jiao Tong University, he received his Ph.D. degree in Shanghai Jiao Tong University. His research interests include camera-based tactile sensors, computer vision, machine learning and their applications to soft robots.

Li Chen is currently pursuing a PhD at the University of Hong Kong (HKU), while also conducting research at OpenDriveLab. He works under the supervision of Prof. Ping Luo and Prof. Hongyang Li. His research interests primarily focus on robotics, encompassing areas such as autonomous driving, robot learning, and robotic systems.

Ran Huang is an associate professor in Fudan University. His research interests primarily focus on thermodynamics, condensed matter physics, polymer chemistry and materials engineering.

Guoying Gu is a professor in Shanghai Jiaotong University. He received the National Science Fund for Distinguished Young Scholars. Now he serves as Associate Editor of IEEE Transactions on Robotics and IEEE Robotics and Automation Letters. He has also served for several journals as Editorial Board Member, Topic Editor, or Guest Editor, and several international conferences/symposiums as Chair, Co-Chair, Associate Editor or Program Committee Member.

Hongyang Li is an assistant professor in HKU Musketeers Foundation Institute of Data Science and Research Scientist at OpenDriveLab, Shanghai Innovation Institute. His research focus is on autonomous driving and embodied AI. He led the end-to-end autonomous driving project, UniAD and won the IEEE CVPR 2023 Best Paper Award. He proposed the bird's-eye-view perception work, BEVFormer, that won Top 100 AI Papers in 2022. He served as Area Chair for CVPR 2023, 2024, NeurIPS 2023 (Notable AC), 2024, ACM MM 2024, ICLR 2025. He will serve as Workshop Chair for CVPR 2026. He is the Working Group Chair for IEEE Standards under Vehicular Technology Society and Senior Member of IEEE.

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