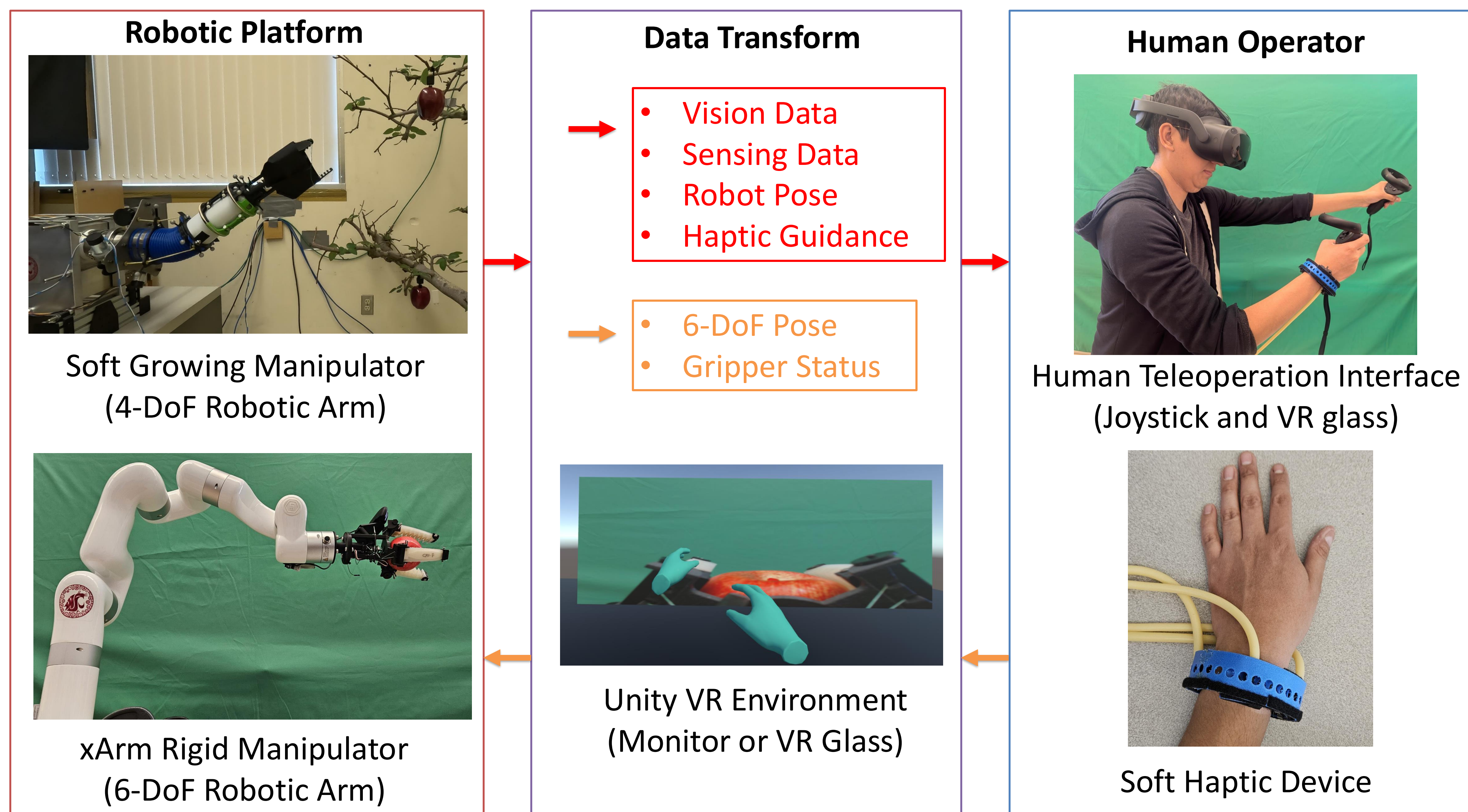


CPS Medium: Smart Harvesting – Enhancing automated apple harvesting through collaborative human-machine intelligence

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Summary: CPS networks will provide increased orchard automation success by leveraging human intelligence. We implement CPS networks with collaborative apple harvesting robots to increase yield and minimize worker risk.



Current Progress Highlight

- A soft wearable haptic device with a **position-to-position 3D mapping teleoperation interface** to ensure the human teleoperator can successfully complete tasks.
- **Optimization** of the teleoperation interface for speed and precision.
- Data collection on **missing identifiable targets** (perception errors) and **failed apple harvesting instances** (robot failure to pick apples).

Next Progress Highlight

- Conduct **human subject studies** to finalize the teleoperation interface.
- Implement the teleoperation interface to allow operation from **Pullman, WA**, for robots located in **Prosser, WA**, and **Itaca, NY**.
- **Reconstruct** failed apple-picking scenarios in a simulated lab environment for testing and **record** successful human operation trajectories.

Outreach Activities

- Demonstrate our system to local growers and workers at the Allen Brothers commercial apple orchard.
- Discuss with growers how to improve the system's performance to better match their needs.



Scientific Impact

- Autonomous crop harvesting that leverages machine learning and human intelligence
- Novel approach for uncertain cases with limited data (perception, decision-making, and actuation)

Broader Impact

- Society
 - Alleviate orchard labor shortage for over 50 local farmers
 - Lower cost of produce with 30% increase in harvest yield
 - Reduce worker exposure to hazards and chemicals
- Education & Outreach
 - Recruited and mentored two Hispanic PhD students from orchard-working families

References

- [1] C. Ninatana, R. Cole, I. Wells, A. Ramos, J. Pilgrim, J. Taylor, R. Dorosh, K. Yoshida, M. Karkee, and M. Luo. "Design and Evaluation of a Lightweight Soft Electrical Apple Harvesting Gripper", IEEE International Conference on Soft Robotics, 2024
- [2] D. Ryan, J. Allen, Z. He, C. Ninatanta, J. Coleman, J. Spieker, E. Tuck, J. Kurtz, Q. Zhang, M. Whiting, J. Luo, M. Karkee, and M. Luo. "Design, Modeling, and Control of a Low-Cost and Rapid Response Soft-Growing Manipulator for Orchard Operations", IEEE/RSJ International Conference on Intelligent Robots and Systems, 2023: DETROIT, MI