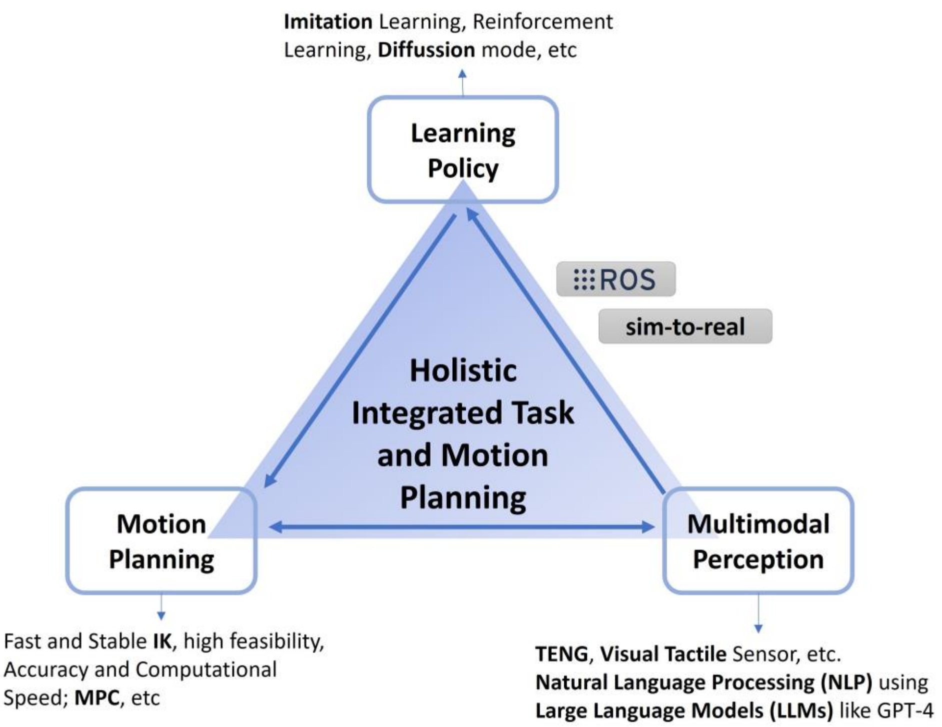
Research Statement -Tianyi Xiang

My research primarily involves formulating **planning, learning, and optimization algorithms** that allow robot **manipulation** platforms to effectively complete tasks.



Applied Scenario:

Household Tasks

Keypoint: cluttered environment, pouring water by smooth trajectory optimisation

Assistant Surgery

Keypoint: pathology-based decision making, tool consistent orientation maintenance, Smooth cutting wound

I've often wondered why intelligent robotic agents struggle to perform at the level of a human. Inspired by Caelan Reed Garrett's "Integrated Task and Motion Planning", I believe part of the answer lies in the way modern robots operate. Current systems tend to work within discrete world configurations, treating learning and motion planning as separate fields.

Consider a simple task like drinking water. A human can recognize the beverage surroundings with hands, eyes, and ears even in shaded environment, and decide how to bring the drink to their mouth, all while generating a smooth, pose-constrained trajectory. During this process, humans naturally check for feasibility—if, for example, the burner on the stove is occupied after grasping a pan, we quickly adapt, moving the obstacle and redoing the task. In essence, humans possess an innate ability to recognize, plan motion, and integrate multi-modal perception within a continuous, dynamic environment. Robots, on the other hand, typically function in a more rigid, segmented manner. **Most efforts today focus heavily on vision-motor decisions** within discrete environments, **overlooking the critical continuous motion planning**, **feasibility checks**, and **multi-modal perception**.

Understanding this gap, **the SOP of my research** can be regarded as **holistic integrated task and motion planning**. To achieve this it, I have divided it into three key areas, each benefiting from my past experiences and future work:

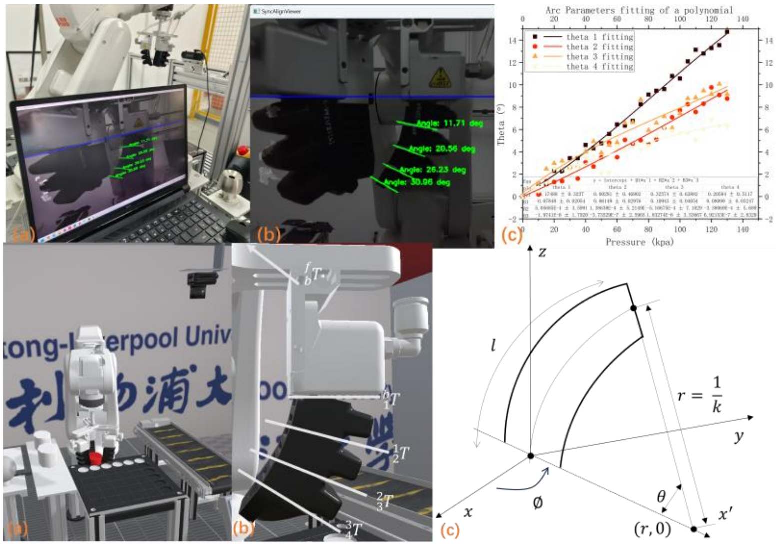
- **(A)** Learning policy: imitation learning, reinforcement learning, diffusion mode.
- **(B)** Motion planning: Inverse Kinematics solved as optimization problem to achieve feasibility, accuracy, computational speed **[1] [2]**
- **(C)** Multimodel perception: Combine vision-motor strategy with visual tactile sensor, TENG, and natural language processing (NLP) with LLM **[3]**.

Publications:

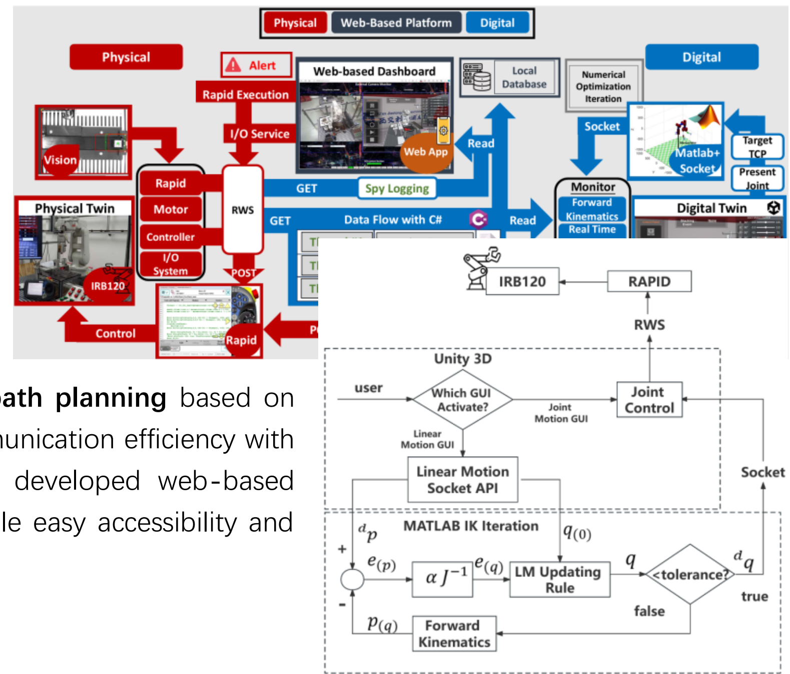
- **[1] Tianyi Xiang[1], et al.** [“A Novel Approach to Grasping Control of Soft Robotic Grippers based on Digital Twin”.] [29th International Conference on Automation and Computing (ICAC 2024) (Accepted)]
- **[2] Tianyi Xiang[1], et al.** ["Development of a Simple and Novel Digital Twin Framework for Industrial Robots in Intelligent Robotics Manufacturing,"] [20th International Conference on Automation Science and Engineering (CASE 2024)(Accepted)]
- **[3]** Xie, B., Xie, Y., Ma, Y., Luo, N., **Xiang, T.** , et al. "High performance $(Zn_{0.5}Mg_{0.5})TiO_3$ ceramics based composite films for powering multi-mode translation unit and human motion monitoring". [ACS Applied Materials & Interfaces (2024)]. [Manuscript submitted for publication].

Previous and Current Work

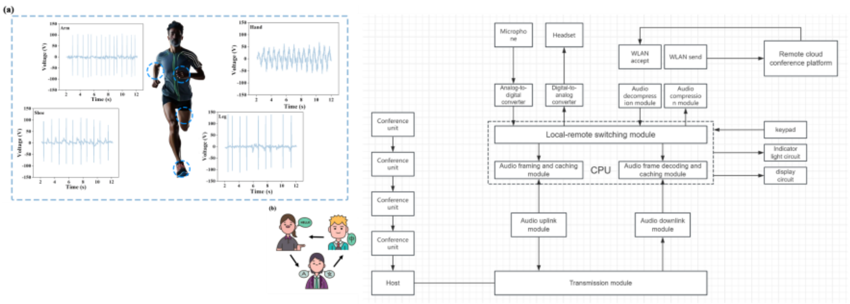
[1]: The developed DT is based on an industrial robot workstation, integrated with our newly proposed approach for soft gripper control, primarily based on computer vision, for setting the driving pressure for desired gripper status in real time. Knowing the gripper motion, the gripper parameters (e.g. curvatures and bending angles, etc.) are simulated by kinematics modelling in Unity 3D, which is based on four-piecewise constant curvature kinematics. The mapping in between the driving pressure and gripper parameters is achieved by implementing OpenCV based image processing algorithms and data fitting. Results show that our DT-based approach can achieve satisfactory performance in real-time control of soft gripper manipulation, and less computational source needed.



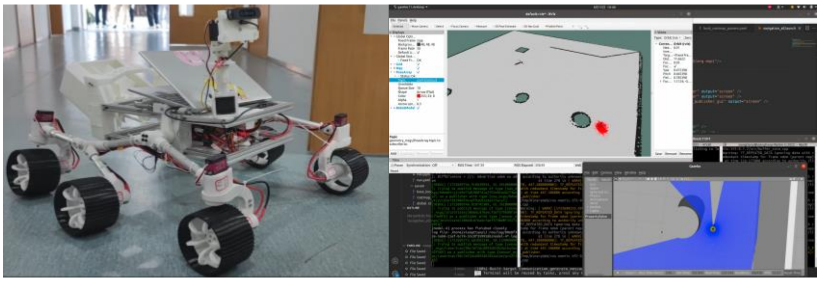
[2]: An easily replicable and novel approach for developing a Digital Twin (DT) system for industrial robots in intelligent manufacturing applications. Our framework enables effective communication via Robot Web Service (RWS), while a real-time simulation is implemented in Unity 3D and Web-based Platform without any other 3rd party tools. The framework can do **real-time visualization and control of the entire work process**, as well as implement **real-time path planning** based on algorithms executed. Results verify the high communication efficiency with a refresh rate of only 17ms. Furthermore, our developed web-based platform and Graphical User Interface (GUI) enable easy accessibility and user-friendliness in real-time control.



[3] Tactile Sensing achieving human motion monitoring. I helped to develop a system for real-time human motion monitoring that leverages multimodal perception to enhance both accuracy and adaptability. By integrating tactile sensing with other sensory inputs such as audio, the system captures detailed, continuous motion data and processes it through a sophisticated framework designed for remote monitoring and interaction. This multimodal approach enables a more comprehensive understanding of human movement, allowing for real-time adjustments and feedback.



[4]: A replica of the Mars Perseverance Rover. The rover employs a rocker-bogie suspension system to navigate the challenging Martian terrain. Ackerman steering system is built. 3D depth vision camera Orbbec gemini pro with Yolo V8 is trained to recognize the QR code as trajectory planning method. And a MPC controller is designed to incorporate to follow the trajectory. Furthermore, we also transfer the mars rover into ROS SLAM-based navigation system with AMCL for adaptive localization. achieving an increase in localization accuracy and a 25% reduction in computational overhead 30%.



[5]:The dynamic optimization of Automated Guided Vehicle (AGV). Applied dynamic optimization of local trajectory planning through LQR, Dual-loop PID, stanely method, and MPC Motion control algorithms to AGV incorporating B-spline and A-star method, with simulation and modelling in Automation studio, MapleSim, and Scene Viewer. Designed self-supervised spline interpolation techniques to generate control points, achieving a maximum deviation of lower 50\%(in unit) in critical turning areas in rare 3\% occurrence probability