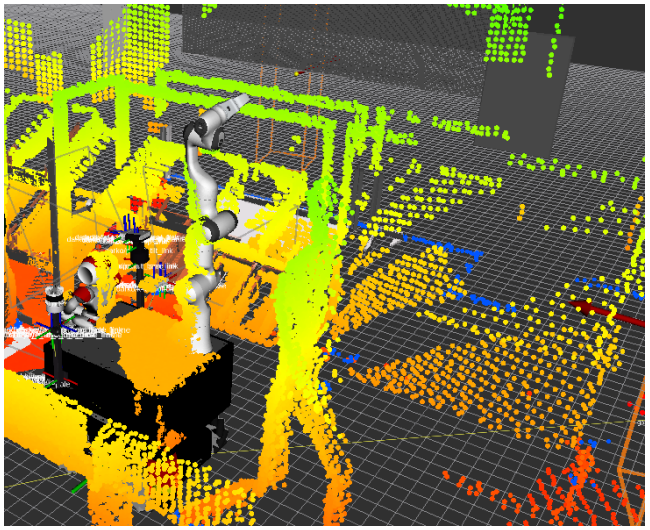
[Forschungspraxis/Internship] Develop a complete simulation of a Robotic Manipulator with impact dynamics



Efficient and fast manipulation is still a big challenge in the robotics community. Traditionally, generating fast motion requires scaling of actuator power. Recently, however, more attention has been paid to "additional ways" for mechanical energy storage and release in order to keep the actuator power requirements baseline lower (just enough to satisfy general manipulation requirements). To introduce "fast mode" manipulation energy could "be injected" from mechanical elements present in the system. It can be useful for tasks such as throwing or other explosive maneuvers.

Bi-Stiffness Actuation (BSA) concept [1] is the physical realization of the previously mentioned idea. There, a switch-and-hold mechanism is used for full link decoupling while simultaneously breaking the spring element (allowing controlled storage and energy release). Changing modes within the actuator (clutch engagement and disengagement) is followed by the impulsive switch of dynamics.

Students are expected to study and understand the physical and mathematical representations of developed concepts. Apply and gain an understanding of multi-DoF manipulator systems, their control, and classifications. Further, using the state-of-the-art simulation frameworks develop a codebase for its representation. The work will be foundational for further research, thus the student is expected to follow best coding practices and document his work.

The student is expected to work on the simulation of the BSA concept. For simplification, one of the modes of BSA can be modeled as a series elastic actuator (SEA). The first step would be to modify rigid robot representation, such that it includes elasticity in joints (modeled as SEA). Implementation details can be found in [2] and the project code in [3] (not necessary to use the same framework for Simulation and Dynamics). Further, dynamics should be extended to handle other modes of BSA as well as impulsive switches between them.

The result should be a usable code base with a minimal reproducible example of a Manipulator executing a throwing maneuver exploiting elastic elements and impulsive mode switches. The simulation will be verified against Matlab implementation (already developed)

Requirements from candidates:

- Knowledge of Matlab, C++, Python
- Working skills in Ubuntu operating system
- Familiarity with ROS
- Robotics (Forward, backward dynamics and kinematics)
- Proficiency in English C1, reading academic papers
- Plus are:
    - Knowledge of working with Gazebo/MuJoCo
    - Familiarity with GIT
    - DesignPatterns for coding
    - Familiarity with Docker
    - Googletest (or other testing framework)

Otherwise, the work is to be divided among two students. One student will be working in MuJoCo[1] or similar (to be decided), the other will develop a simulation for GPU-accelerated computing, using Isaac Gym [4] or a similar engine.

[1] Ossadnik, Dennis, et al. "BSA-Bi-Stiffness Actuation for optimally exploiting intrinsic compliance and inertial coupling effects in elastic joint robots." 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2022.

[2] Mengacci, R., Zambella, G., Grioli, G., Caporale, D., Catalano, M., & Bicchi, A. (2021). An Open-Source ROS-Gazebo Toolbox for Simulating Robots With Compliant Actuators. *Frontiers in Robotics and AI, 8.*

[3] ROS-Gazebo-compliant-actuators-plugin
https://github.com/NMMI/ROS-Gazebo-compliant-actuators-plugin/tree/master

[4] NVIDIA Isaac Sim https://developer.nvidia.com/isaac-sim

To apply, you can send your CV, and short motivation to the Supervisor (with the Senior Supervisor in cc)

Supervisor
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[1] MuJoCo https://mujoco.org/