AMBF-Based Simulation of RAVEN-II Surgical Robot with Realistic Control and Feedback API

Boyang Li[1] (bli24@uw.edu), Haonan Peng[1], Natalie Chalfant[2], Yun-Hsuan Su[2], Blake Hannaford[1], Fellow, IEEE

[1]BioRobotics Lab, University of Washington, WA, 98105; [2]Mount Holyoke College, MA 01075

SYSTEM ARCHITECTURE

- **AMBF:** Physics simulator that emulates the RAVEN-II robot's behavior. It receives control inputs from Robot State and returns sensor feedback.
- **CRTK API:** Accepts standard joint or Cartesian commands (e.g., servo_jr, servo_cr), consistent with real RAVEN-II controllers.
- **Robot State:** It is the central module that manages the robot's internal status. It receives control commands from the CRTK API and joint feedback from AMBF
- **Update Device State:** Synchronizes data from Robot State by sending actuation updates back to AMBF at 1000 Hz.
- **Raven State:** A comprehensive "ravenstate" messages based on data from Robot State. It computes and publishes both raw and derived values (e.g., end-effector pose, motor pose) at 1000 Hz, providing real-time observability similar to the real robot.
- **Raven Controller:** Publish control commands (e.g., from the keyboard or external) as CRTK topics.

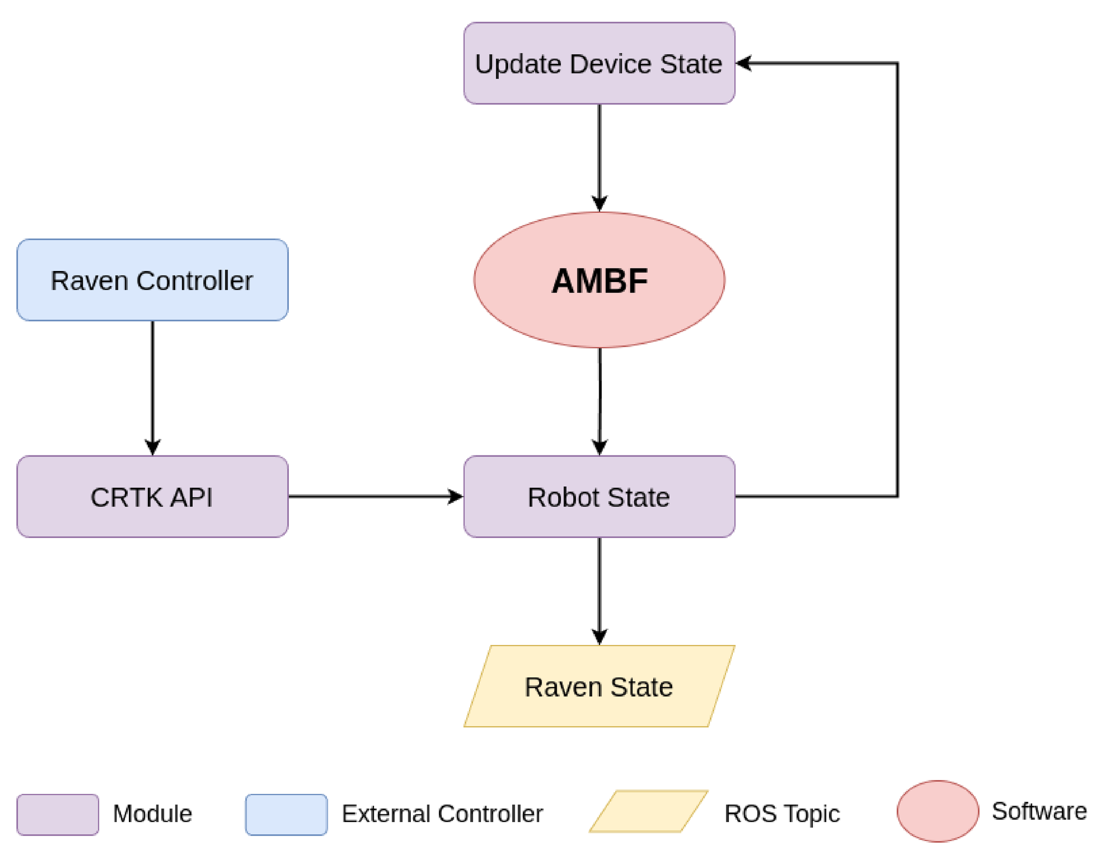

Fig. 1: System architecture of the simulated RAVEN-II, highlighting CRTK-driven control flow and high-frequency state feedback.

RESULTS AND COMPARISON

Aspect	AMBF RAVEN-II	Proposed Framework
Feedback and Data Provided	Multiple ROS topics provide basic joint-level data (e.g.,position, velocity, effort), typically queried via API calls(get_pos, get_rpy, etc.)	A unified RAVEN State topic that publishes comprehensivefeedback including joint pose, end-effector pose, motor pose,encoder values, and additional state details
Update Frequency	Variable update rates without strict synchronization to real-world RAVEN-II control loops	Consistently synchronized with the 1000Hz control loop,ensuring high-frequency and real-time updates
Data Detail	Limited to standard simulation outputs	Extended feedback including additional details such as end-effector position/orientation in the base link frame
Integration Method	Directly manipulates the AMBF simulator through a specificAPI (e.g., set_joint_pos, set_pos, set_rpy)	mplements a standardized CRTK command set to controlthe simulated RAVEN-II (e.g., servo_jr, servo_cr)

RAVEN STATE DATA INTEGRATION

We implemented the "ravenstate" in AMBF to replicate the real RAVEN-II's state feedback mechanism. This message includes both raw and derived data, such as:

- Joint positions, motor and encoder values (linearly derived)
- End-effector pose and orientation (via nonlinear forward kinematics)

All data are encapsulated into standardized ROS messages and published at 1000 Hz, ensuring tight synchronization with the control loop. This detailed and high-frequency feedback enables real-time monitoring, motion planning, and the development of advanced robotic control strategies—closely mirroring the behavior of the physical RAVEN-II system.

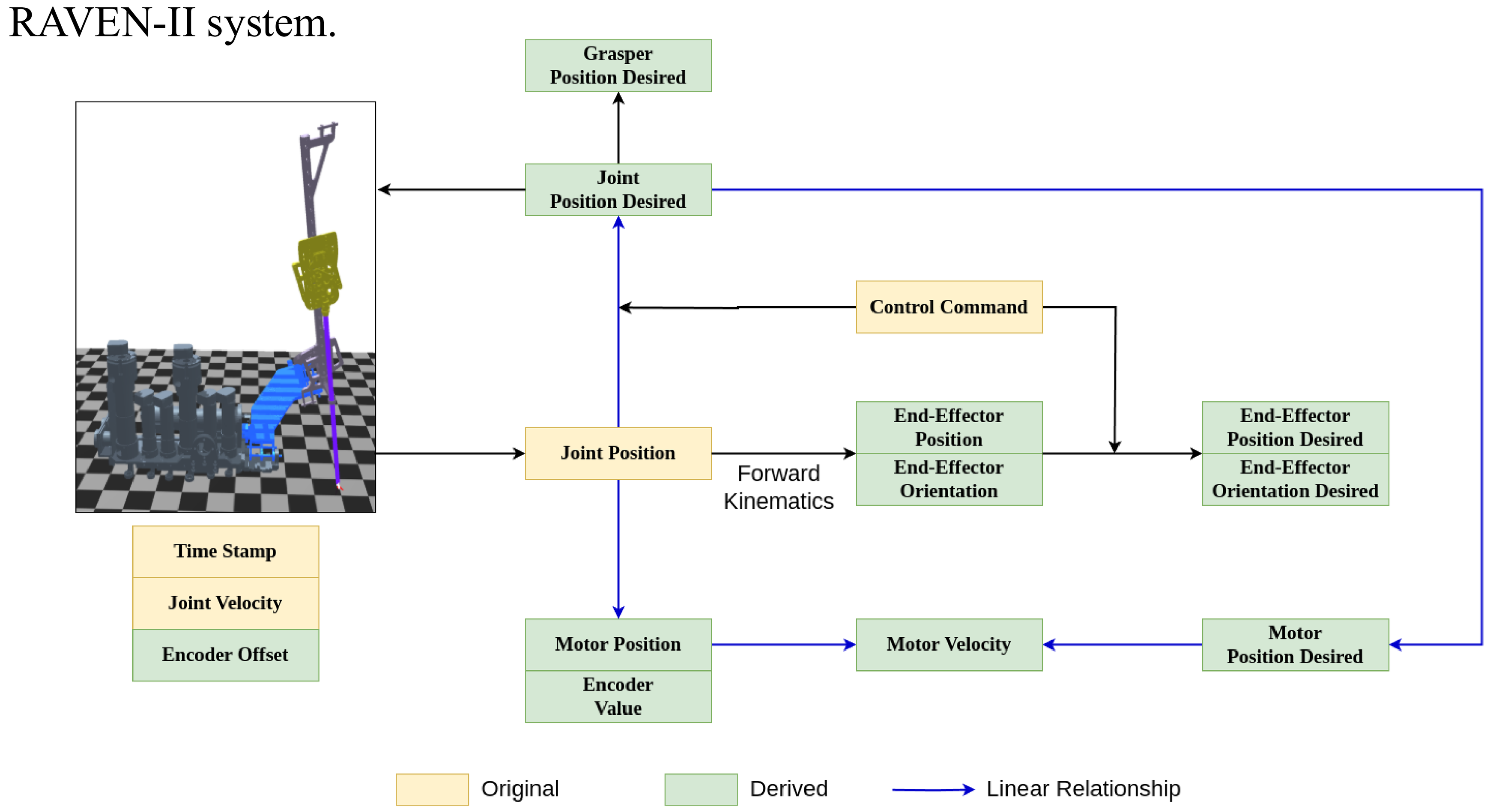

Fig. 2: Data flow and structural dependencies in the simulated "ravenstate".

MOTIVATION

- Surgical robotics offers enhanced precision, dexterity, and minimally invasive procedures.
- Developing and testing new control algorithms directly on hardware is costly, risky, and resource-limited.
- Our work bridges this gap by integrating the AMBF simulator with the CRTK interface, creating a realistic, high-frequency, and modular environment for RAVEN-II research.

LOW LEVEL DESIGN

- **Joint Limits:** Enforces real RAVEN-II range-of-motion constraints for all 7 joints. Prevents unsafe or unrealistic commands.
- **Speed Limits:** Issues warnings and truncate commands that exceed safe velocity thresholds.
- **Smooth Interpolation:** Uses the same trajectory logic as the real RAVEN-II to ensure smooth, realistic motion between poses.

FUTURE WORK

- **Expand State Feedback:** Add Jacobian matrices and dynamic parameters for advanced control and learning tasks.
- **Improved Physical Realism:** Integrate machine learning models to simulate motor torque behavior, enhancing the realism of robot actuation.
- **Bimanual Support:** Extend to include the right arm for full dual-arm surgical scenarios.

MAIN TAKEWAYS

- Combines AMBF RAVEN-II simulation with CRTK's standardized control interface, enabling researchers to control the simulator using the same commands as the real robot.
- A comprehensive "ravenstate" message replicates real RAVEN-II feedback, supporting research.
- Replicates RAVEN-II's motion interpolation, joint limits and overspeed warnings for realistic and safe simulation behavior.