A Modular Platform for Rapid Prototyping of Biosignal-Based Assistive Mobile Manipulator Control Schemes

Carson J. Wynn, Simon S. Padgen, and Laura A. Hallock

***Abstract*—Spinal cord injury (SCI) survivors have diverse residual motor capabilities, illustrating the need for assistive robot interfaces that can flexibly adapt to different user-specific biosignals and control preferences. This work presents a modular ROS 2-based platform for mapping sonomyography, surface electromyography, inertial measurement unit, and keyboard inputs to the degrees of freedom of a simulated Stretch 3 mobile manipulator in MuJoCo. By enabling rapid "plug-and-play" remapping of inputs to robot motions, this platform provides a foundation for developing and evaluating intuitive, dexterous assistive robot control strategies in collaboration with SCI survivors.**

I. Introduction

Spinal cord injury (SCI) survivors could benefit from the ability to control high-degree-of-freedom (DoF) assistive robotic manipulators. However, these potential users exhibit diverse levels of motor function [1]. Current platforms do not generally support this heterogeneity of capabilities, often assuming volitional control of a specific muscle or group of muscles [2] that a given user may or may not be able to activate. In addition, the best way to map these biosignals to robot DoF remains poorly understood [3].

To address the first of these gaps, our team has implemented sensor-location-agnostic control interfaces using sonomyography (SMG) [4], surface electromyography (sEMG), inertial measurement unit (IMU), and keyboard inputs. In this work, to address the second gap, we present a modular platform enabling arbitrary mappings of these biosignals and inputs to different motions of a mobile robot manipulator.

II. Materials & Methods

Fig. 1 illustrates the platform architecture, in which SMG, sEMG, and IMU biosignals are mapped through a ROS 2 interface to control a Stretch 3 mobile robot manipulator simulated in MuJoCo. SMG data are processed into a continuous signal using optical flow tracking as we demonstrated in Sueltz et al. [4]. Surface EMG data are rectified, smoothed, and processed into a discrete signal that activates when the signal exceeds a modifiable threshold (outside a specified refractory period to prevent continuous triggering). IMU data are lightly filtered for noise and also used as a continuous signal. These biosignals — alongside keyboard inputs, used primarily for verification of system components — are then mapped to either joint or end-effector/base positions of the robot as specified in Fig. 1.

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The authors are with the Departments of Mechanical Engineering and Physical Medicine & Rehabilitation, the Kahlert School of Computing, and the Robotics Center at the University of Utah, Salt Lake City, UT 84112, USA.

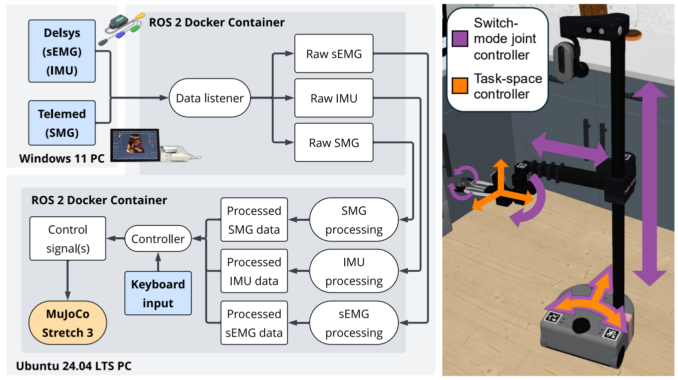

Fig. 1. Modular system architecture (*left*) mapping biosignals and keyboard inputs to simulated Stretch 3 mobile robot manipulator (*right*). Users can continuously control each joint individually (*purple*; e.g., using sEMG above a threshold to switch a continuous SMG signal across joints), or can control the $x/y/z$ position of the end effector or x/θ position of the base (*orange*).

III. Results

Proof-of-concept usage of all integrated platform components was achieved. Specifically, the following workflows were demonstrated, which can be readily combined and augmented: (1) continuous SMG control of each robot joint, switched across joints when sEMG exceeds a threshold; (2) continuous IMU control of each robot joint, switched via keystroke; and (3) task-space control as specified in Fig. 1 via keystrokes. Switching between workflows could be achieved in a few seconds by starting and stopping the relevant ROS nodes.

IV. Discussion & Conclusions

The completed "plug-and-play" system allows for rapid remapping of input signals to robot DoF within a single experimental session, enabling not only seamless transitions between mappings during formal user studies, but immediate incorporation of user feedback during limited hands-on development time. We aim to leverage this platform to undertake such studies and development, prototyping novel control schemes alongside our SCI survivor collaborators and systematically determining the properties of intuitive, dexterous robot controllers.

References

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