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Publication date:
2023

Document version:
Final published version

Document license:
Unspecified

Citation for pulished version (APA):
Xiong, X. (2023). *Closing a Research Loop between Robots and Humans on Online Impedance Adaptation Control*. Poster session presented at European Robotics Forum 2023, Odense, Denmark.

Closing a Research Loop between Robots and Humans on Online Impedance Adaptation Control

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***Abstract*—Variable Impedance control allows robots and humans to safely and efficiently interact with unknown external environments. This abstract introduces online impedance adaptation control (OIAC) for variable compliant joint motions in a range of control tasks: rapid ($< 1s$) movement control (i.e., whipping to hit [1]), arm and finger impedance quantification [2], multifunctional exoskeleton control [3], and robot-inspired human arm control hypothesis [4]. The OIAC has been introduced as feedback control, which can be integrated into feedforward control models. This integration facilitates the understanding of human and robot arm control, closing a research loop between robots and humans. It contributes to ERF2023 by providing an online impedance adaptation controller for human-robot collaboration control which can be beneficial in robotic and biomechanical research.**

***Index Terms*—Adaptive control, variable impedance control, biorobotics, biomechanics**

I. Introduction

Mechanical impedance is an important measure of the relation between a force/torque acting on a mechanical system and the resulting deformation or motion. Human and robot joint impedances are important when they physically interact with the external environment. How they modulate their joint impedance in various interactive control tasks, is a key to successful execution of tasks, and therefore a popular topic in biomechanics and robotics communities.

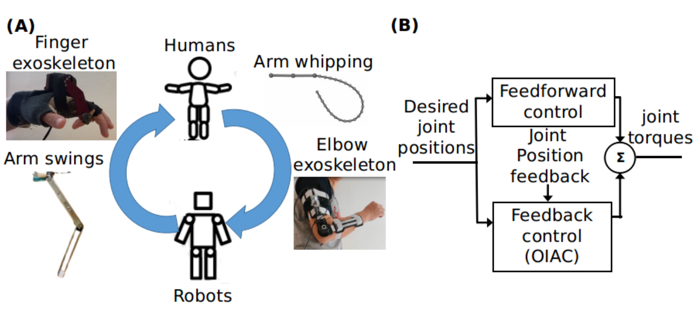

Fig. 1. Closing a research loop between humans (biomechanics) and robots to decode motion intelligence. (A) Researched motions and robots. (B) Feedforward and feedback control.

This work is supported by the Human Frontier Science Program (Grant no. RGP0002/2017), the Brødrene Hartmanns Fund (No. A36775), and the Thomas B. Thriges Fund (No. 7648-2106)

This abstract contributes to ERF2023 by presenting online impedance adaptation control (OIAC) as a feedback controller (see Fig. 1), in which stiffness and damping parameters are online tuned in various applications. The OIAC is limited to a software and simple way for achieving variable compliant robot control. It was applied to three wearable robot applications, i.e., mechanical impedance quantification, assist- and resist-as-needed control. Together with feedforward control, the OIAC provides a simple solution to achieve variable impedance adaptations in a range of human and robot control, compared to existing methods on either complex learning mechanisms or a single scenario.

TABLE I
Integration of feedback OIAC into feedforward control in human and robot arm control (see Fig. 1 (A)). Symbol "-" represents no need for feedforward control.

Feedback	Feedforward	Application	Direction
OIAC	Offline optimized motion primitives	Whipping to hit [1]	human ⟶ robot
OIAC	-	Quantify joint impedance [2]	robot ⟶ human
OIAC	Iterative learning	Multifunctional exoskeleton control [3]	human ⟶ robot
OIAC	Gaussian neural network	Arm swings [4]	robot ⟶ human

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