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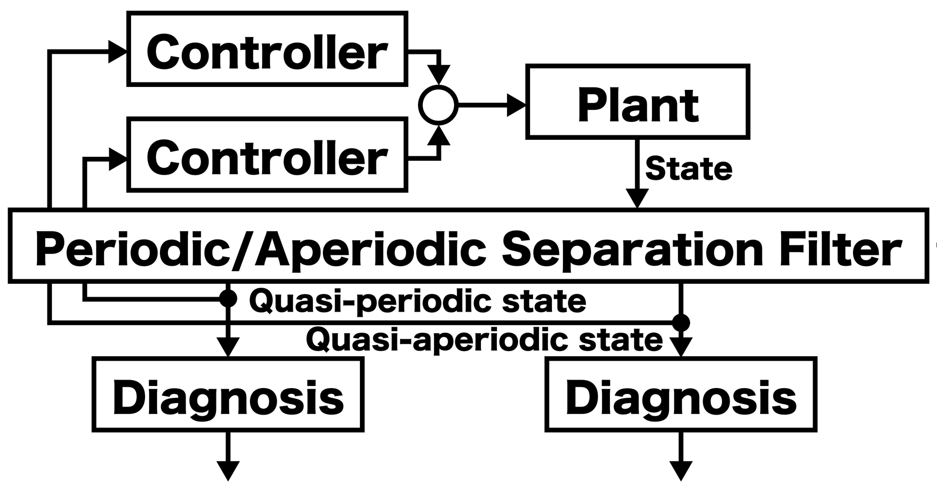
HP YouTube

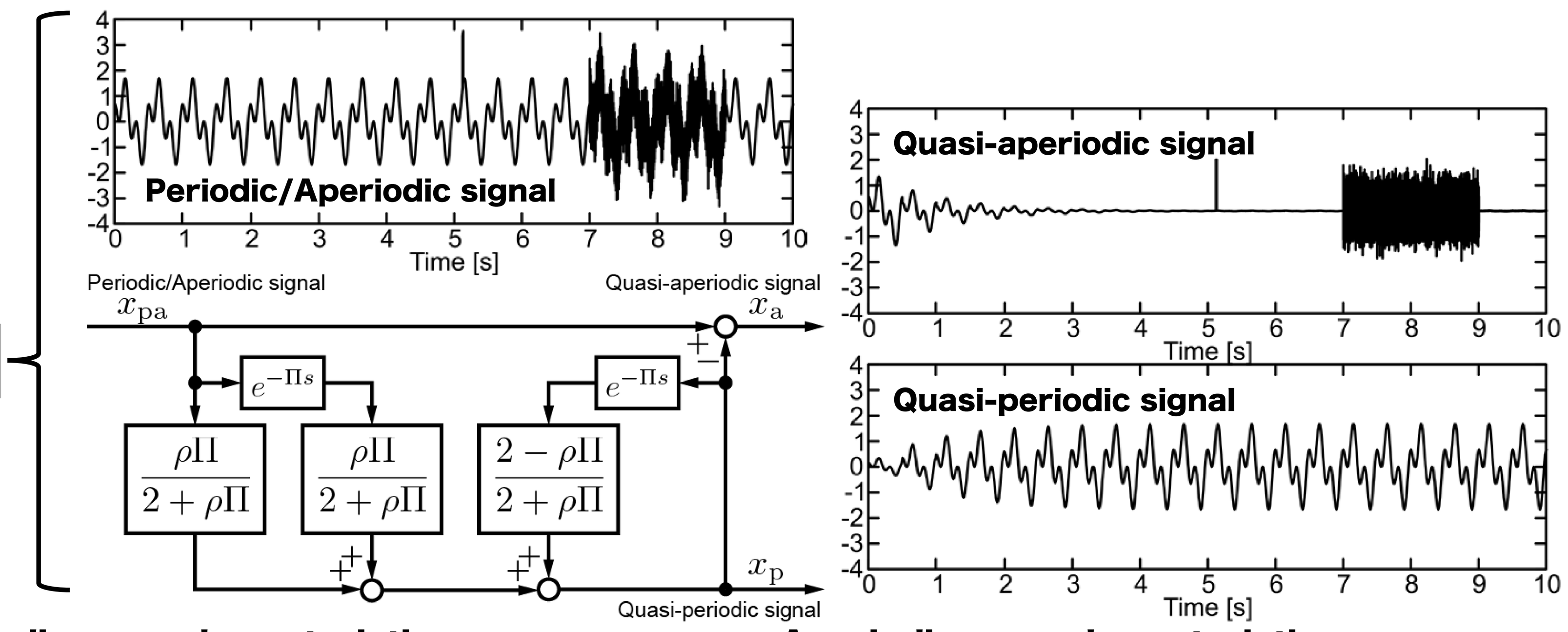

## Overview

We aim to develope robotics and mechatronics technologies to understand, create, and design new machinery movements from the perspectives of control, machinery, and humans. In particular, we have conducted control engineering research focusing on periodic/aperiodic, quasi-periodic, and quasi-aperiodic, developed a mobile quad-arm robot: ARMS, and conducted research on analysis and control of human-robot interaction.

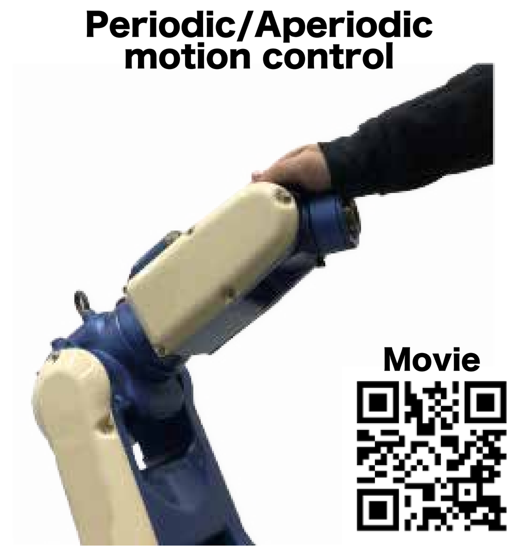
## Periodic/Aperiodic Separation Control[1]

We research definition, analysis, separation, and control technologies for periodic/aperiodic, quasi-periodic, and quasi-aperiodic of a signal. We have defined periodic/aperiodic, quasi-periodic, quasi-aperiodic, and periodic/aperiodic separation functions and proved the closure property, linearity, and orthogonality for them. They have been applied to quasi-periodically precise and quasi-aperiodically safe motion control, anomaly chatter detection for milling, and anomaly leaking package detection.

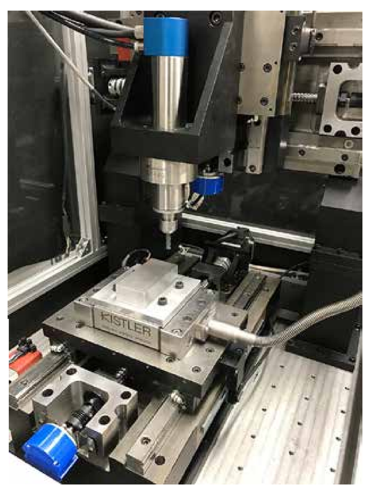


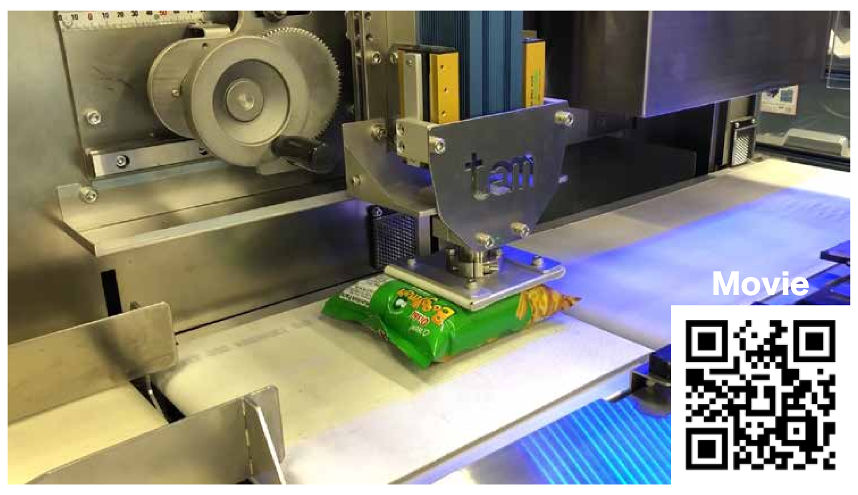

Periodic/Aperiodic motion control



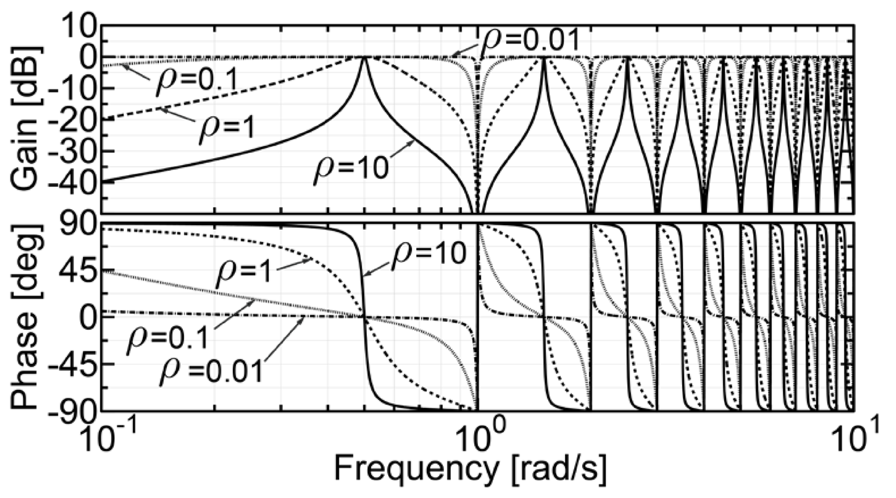

Chatter detection



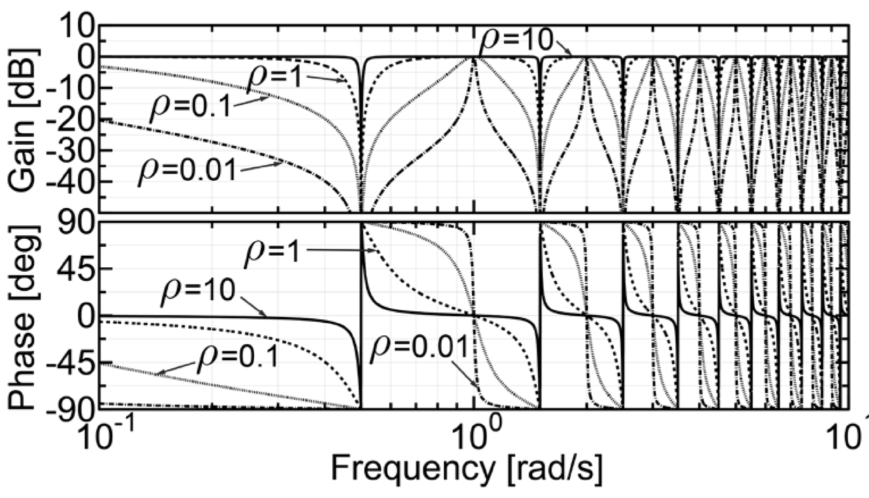
Leaking package detection




Periodic-pass characteristic

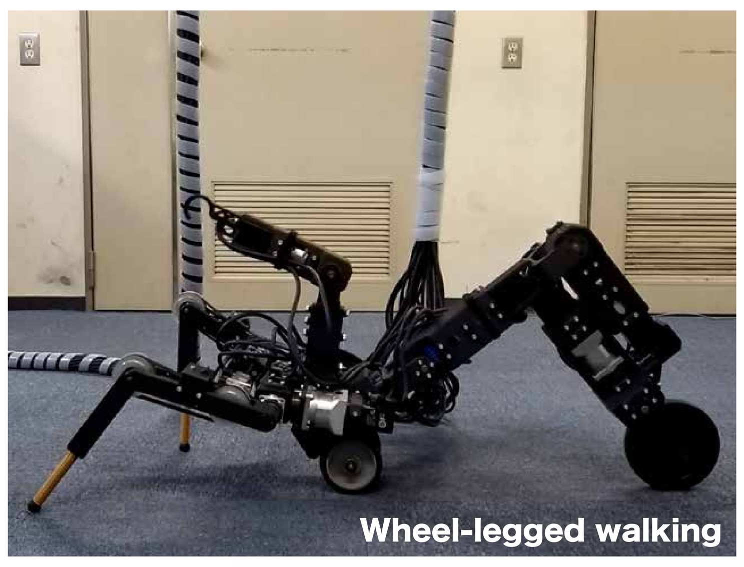



Aperiodic-pass characteristic



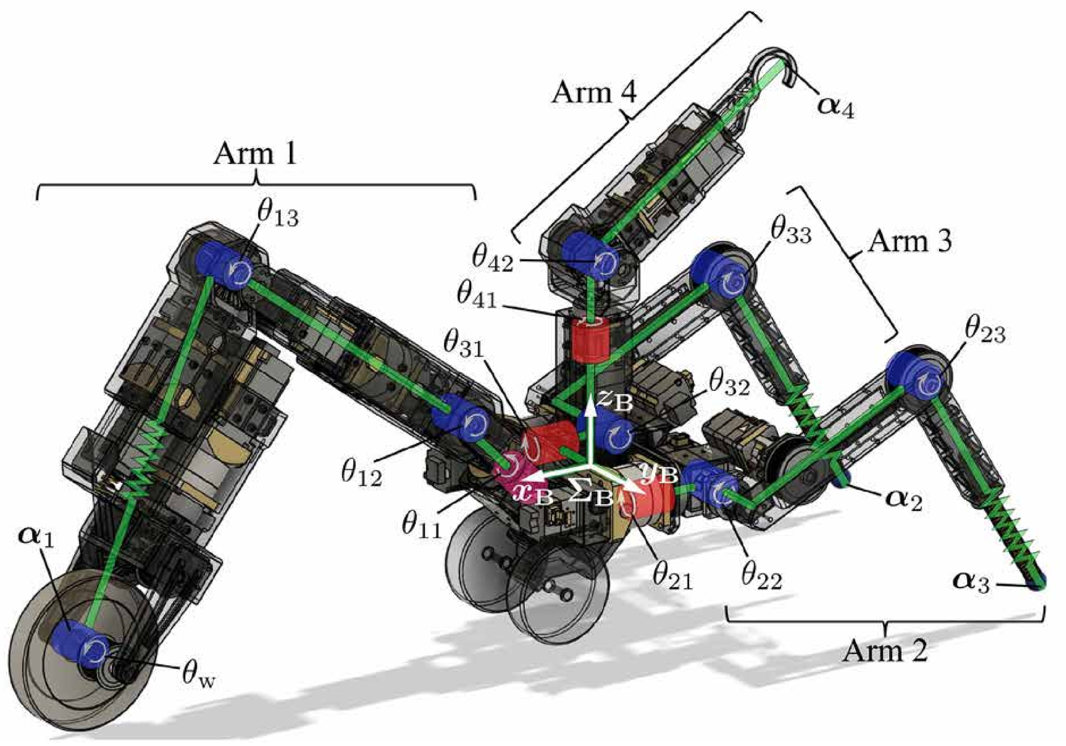

## Mobile Quad-Arm Robot[2]

We develop a mobile quad-arm robot: ARMS for unifying wheel-legged tripedal mobility, wheeled mobility, and quad-arm manipulation. The four arms have different mechanics and are designed to be general-purpose arms to enable the wheel-legged hybrid mobilities and manipulation. The front arm has an active wheel, which is used for wheel-legged tripedal walking and wheel driving with passive wheels attached to the torso. The rear arms are series elastic arms, which are used for wheel-legged tripedal walking, object grasping, and manipulation. The upper arm is used for manipulation only; its position and orientation are determined by coordinating all arms. ARMS was experimentally validated on the basis of the following four tasks: wheel-legged walking, wheel driving, wheel driving with grasping, and carrying a bag.







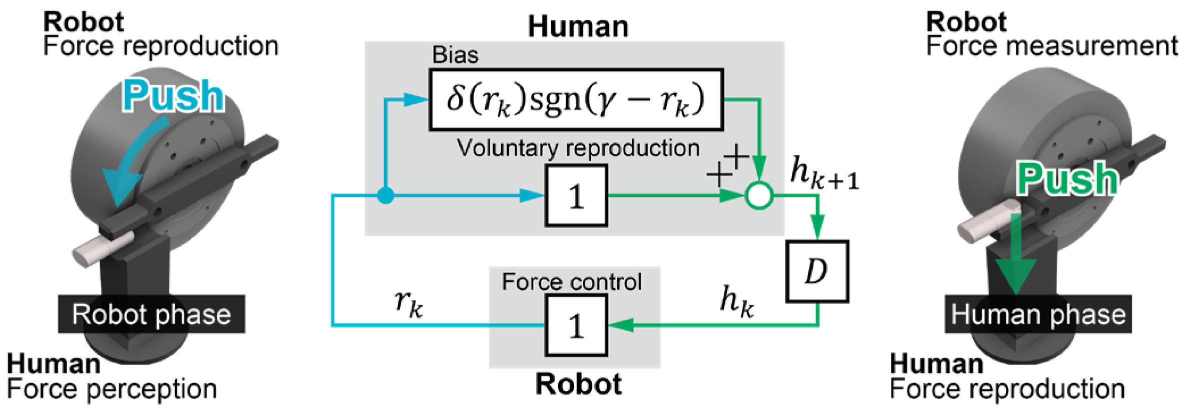





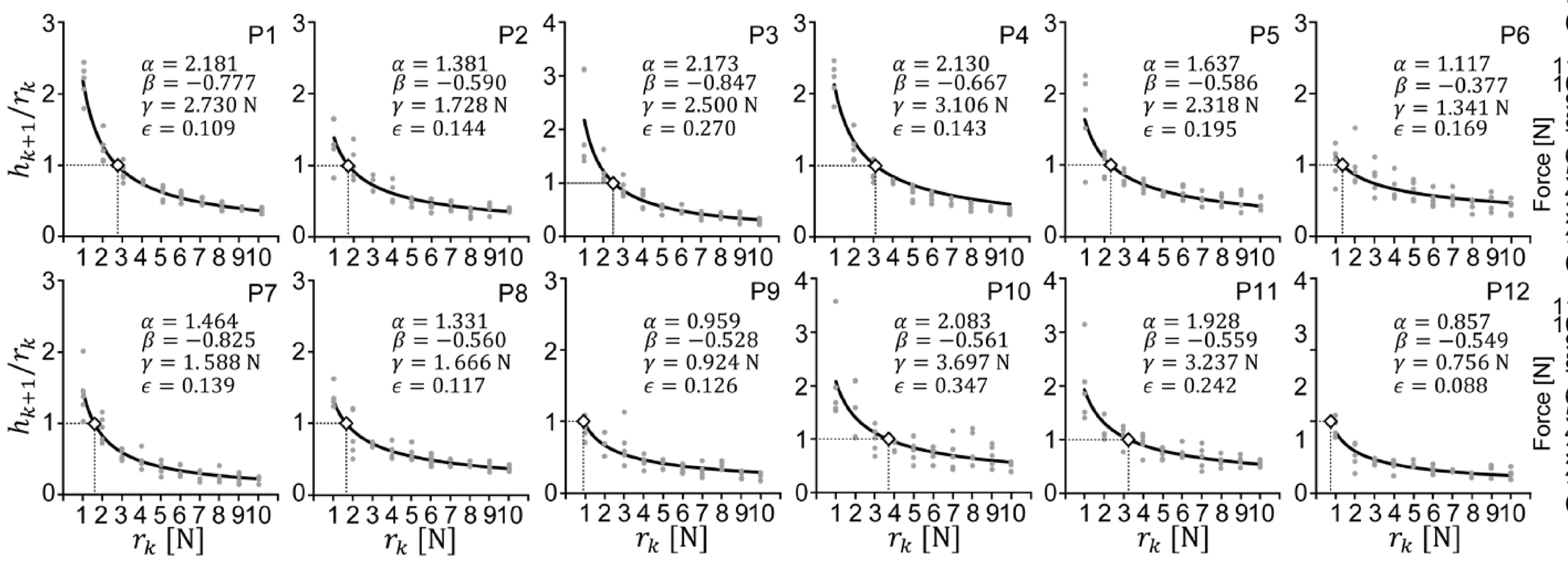
## Stability Analysis for Involuntary Human-Robot Interaction[3]

In human-robot interaction, there is a risk that a feedback loop causes unstable force interaction, in which force escalation exposes a human to danger. Previous studies have analyzed the stability of voluntary interaction but have neglected involuntary behavior in the interaction. In contrast to the previous studies, this study considered the involuntary behavior: a human's force reproduction bias for discrete-event human-robot force interaction. We derived an asymptotic stability condition based on a mathematical bias model and found that the bias asymptotically stabilizes a human's implicit equilibrium point far from the implicit equilibrium point and destabilizes the point near the point. The bias model, convergence of the interaction toward the implicit equilibrium point, and divergence around the point were consistently verified via behavioral experiments under three kinds of interactions using three different body parts: a hand finger, wrist, and foot. Our results imply that humans implicitly secure a stable and close relationship between themselves and robots with their involuntary behavior.

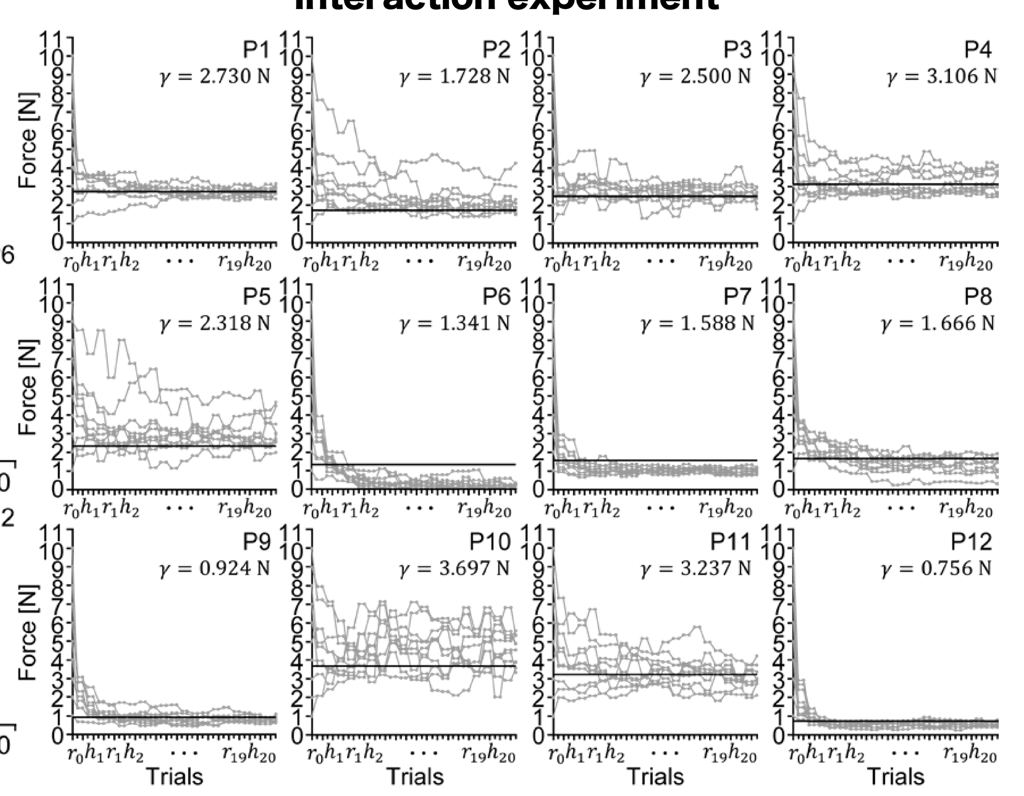
Subjectively marginally stable discrete-event interaction




Force reproduction experiment

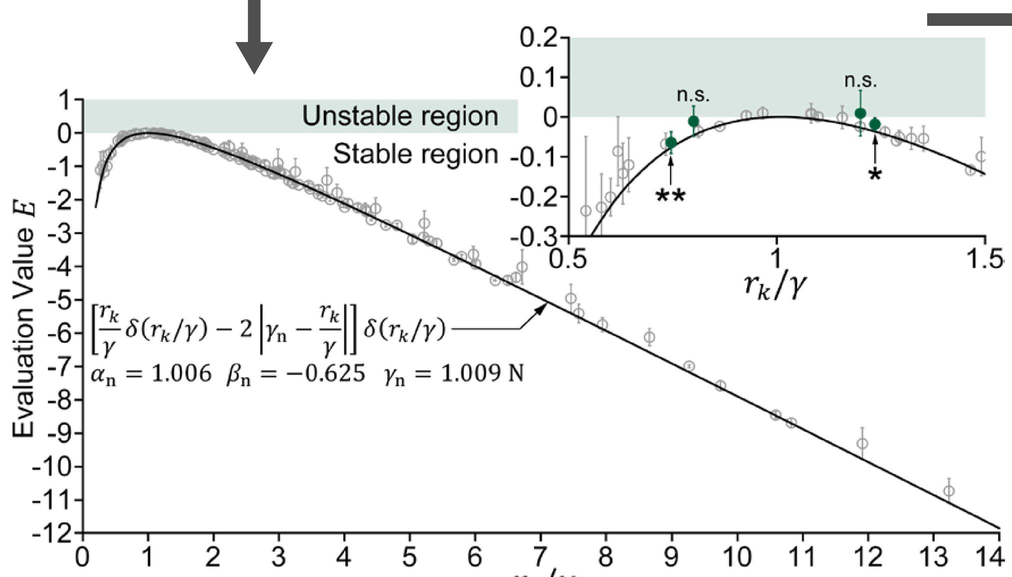



Interaction experiment

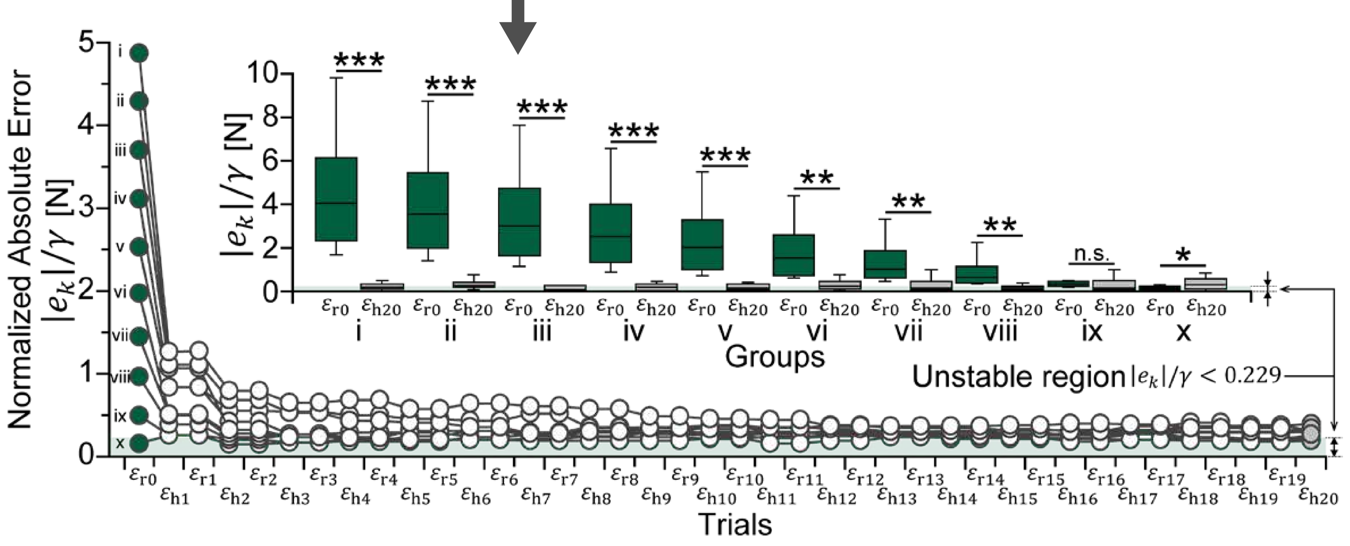



Stability analysis

Prediction of convergence




The interaction force significantly converged toward each participant's implicit equilibrium point.





**Ref.**

[1] H. Muramatsu, "Separation and Estimation of Periodic/Aperiodic State," Automatica, vol. 140, p. 110263, Jun. 2022.
[2] H. Muramatsu, K. Kitagawa, J. Watanabe, and R. Hisashiki, "A Mobile Quad-Arm Robot ARMS: Wheel-Legged Tripedal Mobility and Quad-Arm Manipulation," arXiv, arXiv:2305.01406, May 2023.
[3] H. Muramatsu, Y. Itaguchi, and S, Katsura, "Involuntary Stabilization in Discrete-Event Physical Human-Robot Interaction," IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 53, no. 1, pp. 576-587, Jan. 2023.

[1] [2] [3]