INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title:
Bionic Reflex Control for a Tendon-Optimized Underactuated Anthropomorphic Hand: A Reinforcement Learning Approach

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SHORT ABSTRACT

This thesis investigates advanced bionic reflex control in underactuated, tendon-driven anthropomorphic robotic hands tailored for prosthetic applications. The work emphasizes the replication of human-like dexterity by optimizing actuation parameters—such as pulley radius, spring stiffness, and spring preload angles—to generate five distinct, synergy-based grasp types (power, precision, cylindrical, oblique, and pinch) using potential grasp robustness (PGR) and potential contact robustness (PCR) metrics as the optimization objective function. Central to the study is the development of a novel control pipeline that integrates a wavelet transformation technique for real-time slip detection with a reinforcement learning (RL) framework. The RL agent, trained under domain randomization to accommodate unmodeled dynamics and environmental noise, autonomously adjusts grasp forces to prevent slippage without manual intervention. In addition to slip prevention, the thesis presents an innovative approach to deformation control by eliminating the need for pre-defined labeling thresholds, thus enhancing the bionic reflex by seamlessly adapting to the physical properties of grasped objects. To further bolster the system's resilience, an adaptive sliding mode controller is layered over the pre-trained RL policy. This hierarchical control strategy ensures robustness against matched disturbances and model uncertainties in continuously changing environments. Simulation results confirm that the integrated system can reliably grasp and lift various objects, maintaining high-quality grasps with minimal slippage and deformation. Overall, the proposed methodology represents a significant step forward in developing autonomous bionic reflex controllers that can potentially transform prosthetic hand functionality and robotic grasping research.