INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Robust Control Schemes for a Pediatric Gait Exoskeleton System in Passive-assist and Active-assist Mode

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Over the years, a significant rise in neurological disorders has been observed for different age groups, such as stroke, spinal cord injury (SCI), and cerebral palsy (CP). There are minimal robotic exoskeleton devices available for pediatric gait rehabilitation. Moreover, the control design to achieve the desired gait training in different therapy modes is still open to research and a benchmark problem statement due to significant parametric perturbations and external disturbances (PPED) in pediatric exoskeleton systems. Therefore, this thesis proposes a few robust control schemes for a newly designed pediatric exoskeleton in passive- and active-assist rehabilitation mode. Primarily, the design and prototype development of a 6-DOFs (3-DOF/limb) low-cost stand-aided hip-knee-ankle foot exoskeleton is carried out for pediatric gait rehabilitation in two phases (LLESv1: 8-12 years, 25-40kg, 115-125cm and LLESv2: 8-12 years, 25-40kg, 128-132cm). Two intelligent controllers, i.e., robust LQR-based neural fuzzy (RLQR-NF) and Neural-Fuzzy compensated PID (NF-CPID) control schemes, are investigated for the passive-assist gait tracking of the coupled human-exoskeleton system. The simulation runs show that NF-CPID has outperformed the RLQR-NF against PPED and unperformed against the PP only. The experiments with the proposed control schemes are carried out with a child dummy coupled to *LLESv1*. To avoid the computational complexity of selecting NF hyperparameters and improve the gait tracking, a robust adaptive backstepping (RABS) control is proposed to dealt the presence of PPED. The experimental validations are also carried out for a pediatric subject with GMFCS-Level III coupled to *LLESv2* which confirms the robustness of the proposed RABS control. Furthermore, an adaptive backstepping sliding mode-based subject cooperative control (ABSM-SCC) is proposed to include the subject-exoskeleton interaction during active-assist gait training. A neural-fuzzy-based variable admittance control (VAC) is designed. The effectiveness of the proposed cooperative control scheme is compared with an adaptive backstepping-fixed admittance control (AB-FAC) for two different therapeutic cases, i.e., regular active-assist mode and active-assist mode with the effect of sudden reflex. The proposed cooperative controller has shown a promising tracking behavior, appropriate safe and compliant interaction, in active-assist gait training. The ABSM-SCC is further extended for finite-time and fast convergence of error states by presenting an adaptive backstepping integral-aided singularity-free fast terminal sliding mode-based subject cooperative control (ABISFFTSM-SCC).