A Closed-Loop Markerless Biofeedback System in Pediatric Rehabilitation for Autism Spectrum Disorder and Cerebral Palsy

The Indian clinical landscape lacks objective, high-engagement instruments to support the 21 disability categories mandated by the RPwD Act 2016. Rehabilitation for children with Autism Spectrum Disorder (ASD) and Cerebral Palsy is currently hindered by "Therapy Fatigue" and a persistent Sensory Modulation Gap. Existing environments are static, failing to adapt to a child's real-time emotional arousal or motor planning accuracy. This results in diminished Joint Attention and unquantifiable progress, forcing clinicians to rely on subjective visual estimation of GMFCS levels rather than precise, longitudinal kinematic data. Current interactive systems exacerbate this through rudimentary sensors with high latency and signal jitter, while wearable immersive tools like VR headsets are frequently rejected due to sensory defensiveness.

To address Speech, Occupational (OT), and Socio-Behavioral requirements, "Environmental Bridges" must replace static interfaces with "wearable-free" immersion. Because ASD is a spectrum, systems must recalibrate in real-time based on individual progress and sensory thresholds. Utilizing Depth Sensor Cameras to monitor oral-motor postures and skeletal keypoints allows technology to modulate stimulus intensity, fostering Joint Attention and teaching societal norms such as navigating public spaces within a safe, life-sized projected environment. This creates a documented need for Proprioceptive Actuators environments using projected games to reward correct motor sequences and sensory regulation, bridging the gap between physical exercise and Kinesthetic Academics.

Simultaneously, Locomotor Rehabilitation must shift from manual exercises to data-driven kinematic training. Leveraging Depth Sensor Cameras for real-time skeletal analytics measuring Joint Angular Velocity, Symmetry Index, and Range of Motion (ROM) enables accurate tracking of motor planning without intrusive markers. These environments must act as intelligent actuators, dynamically adjusting interactive targets based on detected muscle fatigue or spasticity to ensure patients remain within an Optimal Challenge Zone. Ultimately, the goal is a unified, accessible platform that combines markerless clinical tracking and adaptive environmental immersion, enabling children to master both physical movement and complex social interactions.