Toward Contact-Aware Humanoid Locomotion: A Modular Foot Sensing Platform

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Stable locomotion in humanoid robots requires accurate knowledge of foot-ground interaction forces, yet existing systems often lack integrated, distributed foot sensing and typically rely on flat, rigid feet that omit the heel-toe rolling found in human gait. To address this, we developed a modular sensing platform with a passive toe mechanism for a new humanoid robot in the AMBER Lab. The system integrates FlexiForce™ force-sensitive resistors (FSRs) amplified through non-inverting op-amp circuits, inertial measurement units (IMUs), and magnetic encoders. Each FSR is individually calibrated to linearly interpolate force from analog voltage output. A custom 4-layer PCB interfaces with a Teensy 4.1 microcontroller, supporting analog readout, 16 status LEDs, dual IMU input, and a PWM-based encoder for passive toe angle measurement. The standalone mechanical design includes toe and midfoot segments, torsional spring toe actuation, a waterjet-cut rubber sole, and helical insert fasteners. All components are mounted to a modular foot structure appended to the Unitree G1 humanoid for initial testing. Final integration will enable measurement of distributed ground reaction forces, segment orientations, and joint angles during walking. This modular platform offers a scalable foundation for contact-aware control to improve future humanoid locomotion and manipulation.