Onboard Multimodal Learning for Data-Driven Decision-Making in Humanoid Robotics

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This work presents the development of a modular bipedal humanoid platform focused on tightly integrating onboard artificial intelligence with multimodal sensor perception for data-driven autonomy. Built upon the Berkeley Humanoid Lite architecture, the system emphasizes the unification of mechanical design, embedded compute, and learning-based control within a fully self-contained humanoid framework.

We design and implement a multimodal sensor array incorporating LiDAR, RGB and depth cameras, and microphone inputs, enabling rich environmental perception across spatial and acoustic domains. Sensor data are synchronized and fused through a ROS 2-based middleware pipeline to produce real-time state estimation, semantic scene understanding, and context-aware environmental representations. These perception outputs inform higher-level decision-making modules, allowing the robot to adapt its locomotion and manipulation strategies based on sensed environmental conditions rather than pre-scripted behaviors.

Locomotion and task policies are trained in GPU-accelerated simulation and deployed to onboard embedded AI hardware for low-latency inference. This architecture enables closed-loop, perception-driven autonomy without reliance on external compute infrastructure. We evaluate system performance in terms of perception latency, decision consistency, and behavioral adaptability in dynamic indoor environments.

The resulting platform demonstrates a scalable approach to embedding AI directly within humanoid robotic systems, enabling real-time, sensor-informed decision-making and advancing the integration of learning-based intelligence in embodied agents.

CCS CONCEPTS • Vision for Robotics • Reinforcement Learning • Robotic Autonomy

Additional Keywords and Phrases: Humanoid Robotics, Multimodal Perception, Onboard Artificial Intelligence, Sensor Fusion, Embedded AI Systems

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