A Scalable and Manufacturable Limb Actuation Architecture for Back-Drivable Humanoid Robotics Using Regenerative Air-Recycling Pneumatics, 3D-Printed QDD Motors, and Reinforcement Learning

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The field of humanoid robotics is currently bottlenecked by a lack of accessibility, high costs, high energy demands, and a lack of ease of manufacturability. This project aimed to create a low-cost, manufacturable/scalable, energy-optimizing humanoid leg via novel 3D Printed QDD motors, dual pneumatic air-recycling systems, and reinforced learning. The first step was to design the overall leg geometry through the CAD software. After this, the motors were designed, 3d printed, and assembled. The assembly included fitting the parts, assembling electronics, and hand-winding the stators. Next, the pneumatic system was developed and tested. Finally, the reinforced learning algorithm was developed to optimize gait and energy use. The data consisted of the RPM at 24V (459.33 RPM), cycles gained via the new pneumatic system and the subsequent energy saved (34 vs 10), and the cost of the project (680.79). Along with this, the gait symmetry and duty factor from the RL program were found. The gait symmetry was one, showing it was efficient and smooth, and the duty factor was 65%, closely mirroring that of real humans. These were then used to develop composite scores for performance, manufacturability, and cost. The composite scores were then used to compare with the current literature in a Pareto graph and show that this project was able to outperform many motors and legs that are the cutting edge in both the market and literature in its objective. The engineering goal was met, and the project occupied the Pareto front, showing that it is low-cost, scalable/manufacturable, and energy optimizing.

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