

Development of a 3-DOF Robotic Arm with Gesture-Based Control to Support Intelligent and Sustainable Additive Manufacturing Environment

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Abstract

The design and control study of a three-degree-of-freedom robotic arm with a micro-servo gripper for pick-and-place applications. The manipulator is a 150 mm lower arm and a 150 mm upper arm powered by NEMA 17 stepper motors and a belt-and-pulley transmission system (gt2). In order to improve torque-to-weight performance, a 16:80 gear reduction was added to the primary shoulder joint and a 37.7mm to 60mm gear reduction to the base swing mechanism. The main focus of this investigation is to develop a real-time control interface that circumvents traditional manual input. By utilizing a computer vision pipeline using Python, powered by MediaPipe, the interface translates human hand gestures into spatial commands. The communication using serial communication (COM3) through an Arduino Uno will then execute the coordinate-based movements together with Inverse Kinematics. The experimental testing identified significant gravitational torque loads at the 150 mm lever arm, particularly at the horizontal lowest point, 0° shoulder angle. A debounce filter was integrated into the software to mitigate signal noise from the AI model, resulting in smoother motion. Finally, the prototype will be demonstrating a successful integration of artificial intelligence and classical mechatronics that contributes a framework for intuitive human-robot interaction to support intelligent and sustainable additive manufacturing environments.

Keywords

Robotic arm, Computer vision, Real-time control interface, Intelligent and Sustainable Additive Manufacturing.