Background

Technological advancements in batteries, sensors, and controls for robots and drones are in turn influencing the push for improving the quality of life of amputees. The initiative is to develop accessible robotic prostheses to replace the typical passive prosthetics, which provides a limited ability to walk but is slower, more strenuous to use, unstable, and forces the user to modify their natural gait pattern because of excess energy usage from non-net-positive mechanical energy. State-of-the-art robotic lower limb prosthetic technologies, however, are still far away from providing a proper quality of life for amputees due to lack of sustainability. Current robotic prosthetics are heavy, bulky, and expensive. For child amputees, these problems are more critical and obvious, as the prosthetic must be scalable to keep up with child growth. Additionally, robotic prosthetics are still not energy efficient to provide a dependable usage in a single charge. All of this is primarily due to the type of actuators used. Researchers at UMichigan created the “Open-Source Bionic Leg” as a baseline of the most common robotic prosthetic devices. There are electro-hydraulic actuators (EHAs) consisting of compact, reliable, and highly efficient components that can be produced through additive manufacturing process (3D printing) which can enable scalable, customizable and affordable robotic prosthetic devices. There are electro-hydraulic actuators (EHAs) consisting of compact, self-contained hydraulic pumps paired with a hydraulic piston, and are electrically actuated and controlled. They have raised the possibility of converting heavy equipment to smart machinery. But these actuators use complex valves and hydraulic fluid lines and tend to be very unwieldy, making them unsuitable for use in wearables and mobile robots. However, a recent hydraulically-propelled drone used an EHA to sustain flight. The beneficial attributes of EHAs are high power density, high reliability, maintenance-free, and cost-effective, and therefore makes them a suitable option for high-efficiency motion transmission. From this, it can be extrapolated that EHAs can provide lower power consumption than traditional electromechanical actuators.

Approaches

Approach One: Actuator—Higher Efficiency

Like how humans convert linear muscle contractions/extensions into joint movements through pressurized body fluids, the proposed fluidic actuator uses a novel approach of combining an electric positive displacement pump (PDP) with a suitable linear or rotary pneumatic/hydraulic actuator controlled through a smart PID servo controller to achieve bionic motion.

Approach Two: Materials and Manufacturing—Beyond Conventional

Several proof-of-concept (PoC) prototypes were built using 3D printed photopolymer housing; however, the ankle is most optimal with aluminum alloy housing. Additionally, careful component selection is important. Empirical tests showed that either a peristaltic pump or an external gear pump can act as a check valve when not moving. External gear pumps allow for the use of high-speed drives, which improve overall efficiency.

Approach Three: Power Management—Energy Conservation

More efficient power management will allow for smaller battery packs that provide adequate amounts of prosthetic usage. Mechanical systems result in lots of energy lost to the environment. This ambient energy can be harnessed using energy harvesting nanogenerators, which can provide enough energy to run onboard electronics. This will allow for battery power to be fully allocated for driving the main motor.

Approach Four: Controller—Energy Efficiency

A smart controller that can fully utilize and monitor the joint, power consumption, and on-board electronics. While closed-loop PID controllers exist, they are not compatible with brushless DC motors, like the ones proposed for use. As such, one must be developed, with the intention of expanding the controller to account for smart energy reallocation, as discussed in Approach Three.

Evaluation Status

Several proof-of-concept (PoC) prototypes were built using 3D printed housing. These were then tested with different pump types as a functional validation and initial parameterization for the theoretical design of an amputee prosthesis. The empirical study showed encouraging torque-to-weight densities (over 4 times the OSI). With the elimination of transmission components through the piston-cylinder pairs and links, the proposed actuator promises significant weight reduction as well.

References


