

A Wholistic Approach for A Dependable Sustainable Bionic Lower Limb Device

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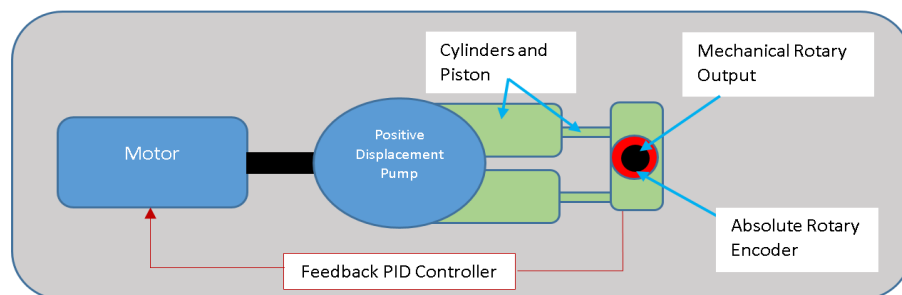
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Technological advancements in batteries, sensors, and controls for robots and drones are in turn influencing the push for improving the quality of life of amputees. The initiative is to develop accessible robotic prostheses to replace the typical passive prosthesis, 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 no net-positive mechanical energy [1]. 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 [1, 2, 3]. For child amputees, these problems are more critical and obvious, as the prosthetic must be scalable to keep up with child growth [4]. 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 technology, using servo motors from drones, gear and belt transmissions, and related control electronics [2].

However, there is a need to explore more energy efficient actuation methods suitable for prosthetics, which can provide higher power transmission efficiency, an option to support low or no power consumption when not moving but still can be backdrivable, simplified components that can be produced through additive manufacturing process (3D printing) which will 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 long flight duration [5]. This research explores the possibility of novel fluidic actuator alternatives for traditional electro-mechanical actuators.

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 (shown below).



Schematics of Proposed Actuator

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 ankle prosthesis. The empirical study showed encouraging torque-to-weight densities (over 4 times of the OSL). With the elimination of transmission components through the piston-cylinder pairs and links, the proposed actuator promises significant weight reduction as well. Empirical tests showed that both a peristaltic pump or an external gear pump can act as a check valve when not moving, thus retaining the pressure

difference between both input and output ports and making the actuator inherently non-backdrivable. This enables a potential power-saving feature for both static and dynamic gaits. For backdrivability, an on-demand bypass fluid channel was tested. The motor torque is isolated from joint torque, and so operates at lower power demand. With the use of higher efficiency motion transmission (98-99% efficiency of piston/belt drive and 90% for fluidic pumps), the design is extrapolated to have lower power consumption than the conventional electromechanical actuators.

References:

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