**Stronger, Smarter, Softer Next-Generation Wearable Robots**

Nevertheless, exoskeletons still present a number of ongoing challenges, including: 1) rigid links with pin joints resist the movement of the biological joints if they are not perfectly aligned [17] and 2) exoskeletons require bulky self-aligning mechanisms [17]–[19]. Rigid systems also have the problem

of large inertia; in particular, adding mass to the legs distally increases the metabolic cost of accelerating and decelerating them (8%/kg for mass at the feet versus 1–2%/kg for mass at the waist) [20]. Due to these effects, wearing such devices often disrupts the natural biomechanics of walking, leading to discomfort or increased metabolic expenditure.

Many basic fundamental research and development challenges remain in actuator development, textile innovation, soft sensor development, human–machine interface (control), biomechanics, and physiology, which provides fertile ground for academic research in many disciplines. While we have focused on gait assistance thus far, numerous other applications are possible, including rehabilitation, upper body support, and assistance for other motions.

**Design and optimization of a new kind of hydraulic cylinder for mobile robots**

The hydraulic power source of mobile robots usually adopts a constant pressure variable pump which can keep its flow automatically varying

to match the total load flow.

The hydraulic power source of mobile robots usually adopts a constant pressure variable pump which can keep its flow automatically varying

to match the total load flow.

**OPTIMIZATION AND DESIGN PRINCIPLES OF A MINIMAL-WEIGHT, WEARABLE HYDRAULIC POWER SUPPLY**

Hydraulic actuation systems have several advantages that make them suitable for wearable human-assistive devices. Hydraulics have force and power densities that are an order of magnitude higher than electric machines [1-3]. This allows for the relatively heavy electro-hydraulic power supply to be worn on the users back or waist, while the lightweight actuators can easily be located remotely using hoses to route the high-pressure fluid. Another benefit of hydraulic systems is that they are shown to have very high precision control, especially when compared to pneumatic or electric systems [4].

**Feasibility of a Hydraulic Power Assist System for Use in Hybrid Neuroprostheses**

Recently, there has been a surge in powered exoskeleton development, including commercial devices such as Rewalk and Ekso [12, 13]. Exoskeletons are able to drive the motion of the limbs for walking and stair climbing with external motors. However, they are limited by the amount of power and the weight of the torque generating motors that must be carried.

Hydraulic systems were selected as an alternative to electric motors for their high torque/mass ratio and ability to be located proximally on the exoskeleton and distribute power distally to

assist in moving the joints.

Hydraulic systems were selected as an alternative to electric motors for their high torque/mass ratio and ability to be located proximally on the exoskeleton and distribute power distally to

assist in moving the joints.

There are three major advantages of using flow discharged from an accumulator as opposed to using flow directly generated from a pump. First, pressure does not have to build from a low pressure which would result in a slow application of torque. High pressure is applied to the cylinder immediately after the DCV has opened which will enable a response time comparable to stimulated muscle. While the average system response time from valve activation to limb movement was 93ms, isometric testing found that the time from valve activation to 90% of the maximum torque output was 159±45ms, which falls within range of stimulated muscle response times (100–300ms) [31]. This response time was independent of input pressure but likely will be influenced by component selection (e.g., tubing and valve switching speed) and any compliance or residual air bubbles in the system. Due to this quick response time, a small fixed displacement pump can be used rather than a larger and costlier pressure-compensated variable displacement pump. The second advantage of using an accumulator to discharge the flow is that pump activation can be kept separate from valve activation. This reduces the maximum instantaneous electric power requirements to drive the hydraulic system. And third one is for safety in that the hydraulic exoskeleton worn by the user is never directly coupled to the pump which will reduce the risk of a malfunctioning pump injecting too much pressure which could harm the individual by moving the joints to undesired positions.

**VARIABLE POSITION AND FORCE CONTROL OF A PNEUMATICALLY ACTUATED KNEE JOINT**

The use of a traditional PID controller demonstrated a severe inability of the controller to compensate for changing pressure differentials (medium compressibility) at the different stages of its operation. This effectively caused a PID controller, which had been tuned at one pressure, to malfunction at a different pressure.

The major limitations of a pneumatic control system are an inability for the control system to compensate for impulse loading without deflection and a requirement that any control system be able to quickly compensate for changes in pressure differentials without excessive overshoot

**An anthropomorphic hand with five fingers controlled by a motion leap device**

Compared to other classes of grippers like jaw grippers [1.2] or tentacular grippers [2], they have obvious advantages because they are more similar to the human hand, both constructively and functionally, considering the human hand as the most perfected gripper [2].

MotionLeap device enables natural interaction between the user and virtual reality at the level of gestures, this is comparable to the interaction based on data gloves. To follow human hand effectively we noted that MotionLeap device is a device by which the human hand gestures can be recognised with great precision.

**Tiny Hydraulics for Powered Orthotics**

As one example of the challenge, a mere 2 kg on each foot of a healthy adult results in a 30% increase in oxygen uptake while 20 kg on the trunk has little impact [8].

The key advantages of fluid power are the high force-toweight and force-to-volume ratios of the actuators eliminating the need for a transmission.

Electromechanical systems carry power through flexible wires that can also be routed around joints but wire cannot be used to separate the actuator from the transmission

For example, looking at the points for 100W of output mechanical power, the electromechanical system is predicted to weigh 428g. A hydraulic system at 100 psi is predicted to weigh 625g, but one at 500 psi would weigh 125g and only 63g at 1000 psi.