Berkeley Lower Extremity Exoskeleton (BLEEX)

The Defense Advanced Research Project Agency (DARPA) funded the BLEEX project in 2000. Last November, U.C. Berkeley's Human Engineering and Robotics Laboratory, successfully demonstrated the first experimental Exoskeleton in which the pilot (i.e., the wearer) could carry a heavy load, while feeling only a few-pound load.

The primary objective of the BLEEX project at U.C. Berkeley is to create a self-powered exoskeleton for strength and endurance enhancement of humans that is ergonomic, highly maneuverable, mechanically robust, lightweight and durable. The first prototype experimental exoskeleton is comprised of two powered anthropomorphic legs, a power unit, and a backpack-like frame on which a variety of loads can be mounted. The device connects rigidly to the pilot at the foot and, in order to prevent abrasion, more compliantly elsewhere. The Exoskeleton allows a person to comfortably squat, bend, swing from side to side, twist, walk and run on ascending and descending slopes, and step over and under obstructions while carrying equipment and supplies. While wearing the exoskeleton, the wearer can carry significant loads over considerable distances without reducing his/her agility, thus significantly increasing his/her physical effectiveness. In order to address issues of field robustness and reliability, the system is designed such that, should the device lose power (e.g., from fuel exhaustion), the exoskeleton legs can be removed with the machine becoming no more than a standard backpack.

The Berkeley exoskeleton system provides soldiers, disaster relief workers, wildfire fighters, and other emergency personnel the ability to carry major loads such as food, rescue equipment, first-aid supplies, communications gear and weaponry with minimal effort over any type of terrain for extended periods of time. The vision for the device is that it will provide a versatile transport platform for mission-critical equipment.

Control Algorithm

The design of the Berkeley exoskeleton benefits from the advantage of human intellect and the strength advantage of the exoskeleton: the human provides an intelligent control system for the exoskeleton, while the exoskeleton's actuators provide most of the strength necessary for performing the task. There is no joystick, pushbutton, or keyboard to “drive” the device; the pilot becomes an integral part of the exoskeleton while walking, with the exoskeleton carrying the majority of the load. The control algorithm ensures that the exoskeleton moves in concert with the pilot with minimal interaction force between the two. The control scheme needs no direct measurements from the human or from the human-machine interface (e.g., sensors between them). The controller, based on measurements from the exoskeleton only, estimates (i.e., computes very quickly) how to move so that the wearer feels very few forces. This novel control scheme is quite elaborate, but it is an effective way to create locomotion when the area of contact between the wearer and the machine is unpredictable.

Electronics

The above control code resides on a body LAN (local area network). The electronics platform uses a high-speed synchronous ring network topology where several electronic modules can reside in a ring. Each module is in communication with several sensors and actuators in close proximity. The data gathered by each module is encoded and transmitted digitally to a computer through the ring. This is similar to the way that several computers on a LAN are able to communicate with each other. The experimental exoskeleton electronics have three rings, in which two of the rings (associated with two legs) include five modules. The third ring can either be interfaced to a Graphical User Interface for debugging and data acquisition or used to accommodate other electronic and communication gear that are not related to the exoskeleton, but which the pilot must carry.

Design

The design of the Lower Extremity Exoskeleton differs from the design of conventional automated robotic systems for two reasons: 1) the device interfaces with its human operator on a physical level; and 2) the device requires robustness under extreme operating conditions and environments. Clinical Gait Analysis of human gaits was used as the primary basis for the physical requirements of the exoskeleton. This data was used to insure sufficient kinematic flexibility to allow natural dynamic movement. The data were additionally applied to the designs of the device's architecture, actuation and power distribution sub-systems of the exoskeleton. The researchers have also identified the "worst case" mobility requirements, including payload specifications, necessary speed and terrain parameters. The exoskeleton team developed an architecture that is minimally felt by the wearer while conferring maximum assistance and locomotion to the wearer. Two exoskeletons with two different sizes were designed and built at Berkeley.

Power Source

Every effort was made to ensure that the U.C. Berkeley exoskeleton is energetically autonomous and is field re-fuelable. A significant challenge in the design of the lower extremity exoskeleton was the development of a power supply and actuation system that would satisfy its power and energy requirements for a long mission. The Berkeley exoskeleton uses a state-of–the-art small hybrid power source, which delivers hydraulic power for locomotion and electrical power for the exoskeleton computer.

Work on the exoskeleton project on-going, with the focus turning to the miniaturization of exoskeleton components, the development of a smaller, quieter and more powerful power source and a faster and more intelligent controller.

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