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Human Power Extender: A Material Handling System for Distribution Centers

H. Kazerooni

Mechanical Engineering Department
University of California
Berkeley, CA 94720 USA
E-Mail: kazerooni@euler.berkeley.edu

Abstract: A human's ability to perform physical tasks is limited by physical strength, not by intelligence. We define "extenders" as a class of robot manipulators worn by humans to augment human mechanical strength, while the wearer's intellect remains the central control system for manipulating the extender. Some major areas of application for the extender include manufacturing, construction, loading and unloading aircraft, maneuvering cargo in shipyards, foundries, mining, or any situation which requires precise and complex movement of heavy objects. Our research objective is to determine the ground rules for the control and design of robotic systems worn by humans through the design, construction, and control of a prototype experimental hydraulic extender for manufacturing operation.

Definition: Figure 1 shows an experimental extender at the University of California, Berkeley. The goal of this research is to determine the ground rules for a control system which lets us arbitrarily specify a relationship between the human force and the load force. In a simple case, the force the human feels is equal to a scaled-down version of the load force: for example, for every 100 pounds of load, the human feels 5 pounds while the extender supports 95 pounds. In another example, if the object being manipulated is a pneumatic jackhammer, we may want to both filter and decrease the jackhammer forces: then, the human feels only the low-frequency, scaled-down components of the forces that the extender experiences. Note that force reflection occurs naturally in the extender, so the human arm feels a scaled-down version of the actual forces on the extender without a separate set of actuators.

An electric extender, composed of two arms and two legs, was designed and built for maneuvering boxes (Figure 1). A molded rubber handpiece housing a piezoelectric force sensor serves as the interface between the operator and the machine. The wrist joints are arranged in a spherical configuration with the handpiece at the center of their axes. Thus positioning of a load is accomplished by actuation of the first three powered joints, while orientation of the end effector is achieved through wrist motions. The wrist has been designed to have a degenerate configuration for all possible orientations of the wrist in the targeted work envelope. Such an architecture insures that any loads applied to the end effector will not manifest themselves in moments which must be supported by the operator.

Each leg has four serial degrees of freedom, and, in this case, three additional "false" degrees of freedom are used in the interface between the operator and the machine. Similar to the those of the arm, the upper three leg joints are powered. To avoid the need of a long "foot" to support torque at the "ankle" of the machine, there are no actuators below the knee; the final degree of freedom for the leg is the rolling contact that occurs between the ankle and the ground.

At the ankle, rotary and linear bearings provide degrees of freedom which are intended to isolate a foot pedal to which the operator's foot is connected through a bicycle cleat. This cleat further

allows for rotary motion of the foot from side to side. A three-axis force sensor is mounted in between the foot pedal and the ankle bearing assembly. The links used in the arms and legs have been constructed from a carbon-composite material formed around a structural foam core. Aluminum inserts bonded to the composite links are used to connect each link end to its corresponding actuator. The links are curved so as to avoid interference with the operator and the rest of the machine.

The electric system, designed and built at UC, Berkeley, is composed of two arms and two legs and is used to maneuver boxes in warehouses. During operation, the extender transfers to the worker's arm, as feedback, a scaled-down value of the actual load which the extender is manipulating: the worker "feels" the load weight in the manipulations.

References:

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