Small-Scale Hydraulics for Human Assist Devices

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Motivation: Human assist devices such as hand tools and orthotics require high force, low speed, compact size, and light weight, which match hydraulics. Traditionally, hydraulic systems are used in applications that require large amounts of power so components are large and heavy. To apply hydraulic technologies to human assist devices, traditional hydraulic components must be scaled down to appropriate power levels, that is, from thousands of watts to about 100 W. To apply small-scale (10–100 W) hydraulics to human assist devices, three steps were taken. First, a hydraulic ankle foot orthosis (AFO) was built and tested to understand the feasibility of using small-scale hydraulics in human assist devices. Second, a small-scale electrohydraulic actuator (EHA) system was built to identify the gaps between the desired small-scale hydraulic components and the smallest off-the-shelf hydraulic components. Third, basic fluid mechanics and structural equations were used to model the efficiency of small-scale hydraulic components, which is the key to miniaturize traditional hydraulic systems. Results: The AFO platform showed that sufficient torque and range of motion can be realized with a hydraulic system but confirmed the need for small hydraulics to reduce the weight and bulk. The EHA system showed that the smallest off-the-shelf components are oversized for a small-scale hydraulic system and identified the need for custom small-scale hydraulic components. The efficiency models showed that reasonable efficiencies are achievable for small-scale hydraulic components, but different design rules are required.

Multimodal Automated Quantitative Sensory Testing System for Pain Research

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Chronic pain is a significant public health problem throughout the world. In the United States alone, chronic pain accounts for an estimated $61 billion a year in lost work productivity and is the leading cause of disability and reduced quality of life in the working population. Treatment of pain is therefore an important and active area of research. For each new treatment modality or drug developed, quantitative evaluation is necessary to judge its efficacy and optimal target population. Quantitative Sensory Testing (QST) provides a standardized and quantifiable methodology to study pain sensitivity in humans. A QST protocol describes a series of noxious and nonnoxious stimuli (e.g., heat, pressure, or electrical) delivered to a patient, and a semi-objective method for the patient to rate their perception of each stimulus. Using this information, clinicians are able estimate the level of a patient's pain sensitivity. This information can be used in the diagnosis of the pain source, the prediction of future pain occurrence, or the assessment of treatment efficacy. In traditional QST, fairly rudimentary devices have been used to deliver stimuli, such as manual dolorimeters or von Frey filaments; however, these methods suffer from inaccuracies primarily due to their operator dependence. More sophisticated QST devices that are also available are large and difficult to use, thus limiting their clinical applicability. This paper presents the motivation, design, and evaluation of a novel pressure-type QST system termed the multimodal automated sensory testing (MAST) system. The system's primary benefit is that it significantly reduces operator based experimental variability by automatically delivering stimuli and prompting the patient for feedback. In addition, its small size and ease of use allow it to be used clinically at the point-of-care. We present encouraging results illustrating that the MAST system offers reduced experimental variability and is able to discriminate between healthy human subjects and those with chronic pain. The advantages of using this type of device in clinical research will be highlighted with additional data showing that this system permits evaluation of response variability and tissue characteristics previously hidden in the measurement "noise" of current pressure-type QST systems.