[0257] The present subject matter can be used for the various stages of therapy. In particular, the system can be used to drive the patient limbs in order to expand the range of motion. In addition, the system can be configured to provide a full spectrum of assistance or resistance.

[0258] In the context of neural signaling, the system can be used as a power orthotic device.

[0259] For training purposes, the present subject matter can be used for simulating human performance involving, for example, manipulation of an object, or executing an artistic or athletic performance.

[0260] In addition the present subject matter allow a user to experience a haptic or virtual reality experience.

[0261] As a human amplifier, the present system allows a user to interacting in an environment with a physical object. The user can apply a force on the object and together, the user and the exoskeleton share the load. The user will feel a fraction of the load. In one example, the system can be configured so that the exoskeleton carries a selectable portion of the load.

[0262] In addition the present subject matter allow a user to experience a haptic or virtual reality experience. For example, a user can be placed in a scene of an environment that includes a virtual object rendered in three dimensions. In the virtual scene, the user can, for example, move their hand out and touch the object with a sensing element. The present subject matter allows the user to feel the object. In addition, the user can feel a force corresponding to the feedback that would be encountered upon touching the object. For example, if the user attempts to penetrate the object the feedback force may prevent the user from going inside and instead, the object may force the user's finger around to the side. Alternatively, if the object is flexible, then the user will see the deflection on a display and the user will feel the various levels of resistance corresponding to the device flexibility. The feedback information is delivered to the user using various elements of the exoskeleton, thus corresponding to the actual feedback experienced in a real environment.

[0263] In addition, the user can interact in a virtual environment having objects that affect the performance in a manner that corresponds to a real environment. For example, if a user inserts an arm in a hole, such as a tube, then in a simulated environment, then their range of motion will be affected. When inserted a short distance, for example, the range of motion of the forearm only is restricted. If inserted farther, then both the upper and lower arms are limited.

[0264] The individual joints of the present subject matter are separately controllable and can be operated individually or simultaneously. In addition, the software controls the position and movement of the various elements of the exoskeleton in a manner corresponding to the virtual environment.

[0265] Some examples of the present subject matter include a communication system, such as a communication network or a dedicated communication line that allows portion of the system to be distributed in more than one location. For example, using a communication network such as the internet, a user wearing an exoskeleton is able to participate in a haptic experience. As such, a user in Minnesota can touch and manipulate an object located in an environment existing in Washington. In addition, the user can touch and manipulate a simulate object that exists only in a virtual environment.

[0266] In another example, the user wearing an exoskeleton is able to work with and interact with a physical therapist located in a remote location. A remote therapist can hold and manipulate a patient's arm from a remote location and a haptic feedback signal returned to the exoskeleton can allow the patient to experience the resulting forces applied by the therapist.

[0267] Other examples are also contemplated. For example, an instructor fitted with an exoskeleton structure as described herein can provide interactive training to a number of students wearing an exoskeleton. In one example, a user wears both a left and right limb exoskeleton structure and one side is used to train or mirror behavior of the other side. Such an application allows a user to self-train following an asymmetric impairment or other condition such as stroke.

Conclusion

[0268] The 7-DOF exoskeleton is a relatively lightweight, high-performance system that facilitates full-workspace and ROM. Proximal placement of motors, distal placement of pulley reductions, and open mechanical human-machine-interfaces were incorporated into the design of the Exoskeleton. Additional characteristics include low inertias, high-stifffiess links, and back-drivable transmissions without backlash.

[0269] The myoprocessor enables a neural interface between the human operator and the exoskeleton system. This neural interface contributes to a natural and stable integration between the wearable robot and the user such that the user views the exoskeleton as an intuitive extension of his/her body.

[0270] The powered exoskeleton system can increase the load carrying capacity of both healthy and physically impaired operators. In the former case, it can be used as an upper limb orthosis. For a patient with a neurologic disability to employ any powered exoskeleton, he or she may have some minimal motor control abilities in order to generate EMG signals. The powered exoskeleton allows additional functional activities to be performed by patients with weakness. In persons with quadriplegia, voluntary sEMG signals are frequently obtainable from muscles with nearly complete paralysis, and the ability to generate sEMG activity can be enhanced through a short biofeedback training protocol. Measurable sEMG signals from muscles without detectable voluntary contraction force can be used with the present subject matter. Additionally, since functional use of a partially paralyzed limb improves motor recovery in many central nervous system disorders, use of the device holds the potential for enhanced motor recovery.

[0271] The present subject matter serves as an assistive device and can be worn by the user as an orthotic device. The device functions as a force feed-forward human amplifier. The joints and links of the structure correspond to those of the human body and its actuators share a portion of the external load with the operator. The human-machine interface (HMI) is set at the neuromuscular level of the human physicolgical hierarchy using the body's own neural command signals as one of the command signals of the exosk-