Design of a Novel Portable Knee Ankle Orthotics

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***Abstract*— We present an intelligent compact and modular knee-ankle-foot robot for gait rehabilitation at outpatient and home settings. The robot is designed with a novel compact compliant force controllable actuator for safe human robot interaction. A prototype of the robot has been developed and tested with healthy human subject to prove the design.**

I. Background

With the population aging, stroke is becoming one of the leading causes of adult disability, such as gait impairment. Robots have been developed to overcome the limitations of manual therapy for rehabilitation, but most of them are bulky, expensive, and available only to big hospitals [1]. A significant portion of patients still have residual gait impairments, such as knee hyperextension and drop foot, after discharge from hospitals. Therefore, there is a great need for a home-based wearable robotic system for gait rehabilitation. Numerous robots have been developed specifically for the ankle joint to tackle the drop foot problem [2] or to aid the knee joint [3]. However, research aimed at providing active assistive torque to both the knee and ankle was very limited due to the added mechanical design complexity. We present an intelligent compact and modular powered knee-ankle-foot orthosis for chronic stroke patients to conduct gait rehabilitation at outpatient rehabilitation centers or at private homes. We developed a novel compact compliant actuator and linkage mechanism to achieve light-weight and modular design.

II. Design of the Robot

Figure 1 shows the robot. The modular system consists of an ankle foot module and a knee module. Each module is driven with the same compact compliant force controllable linear actuator. It is known from human biomechanics that the range of motion of the lower limb joints is within 90^o during normal walking. Therefore, a simple rocker-slider mechanism is used to achieve a compact design, which is optimized based on the human gait kinematics. The structure of the system is made of lightweight carbon fiber composite material. The total weight for the mechanical module is estimated to be less than 4Kg.

Safe human-machine interaction requires compliant actuators that can achieve force control with low output impedance and back-drivability. We developed a novel and compact series elastic actuator (SEA) that overcomes the limitations of current SEA designs: comprise between force transmission and stiffness. As shown in Fig. 2, we introduced an extra torsion spring right after the motor to handle the high force range operation, which makes it possible to use a very soft spring for the low force range. The result is a truly compliance actuator with high force control fidelity, yet wide force range and control bandwidth and compact design as reported in [4]. The actuator designed for this robot can provide full assistive force for both knee and ankle joint.

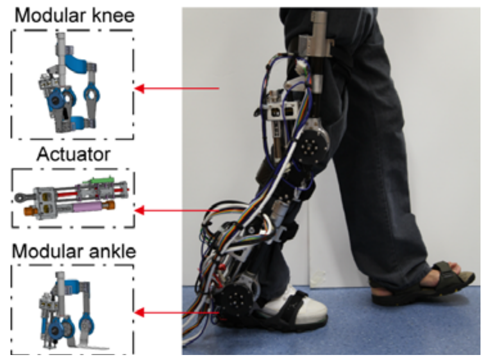

Figure 1. The Prototype of the Robot.

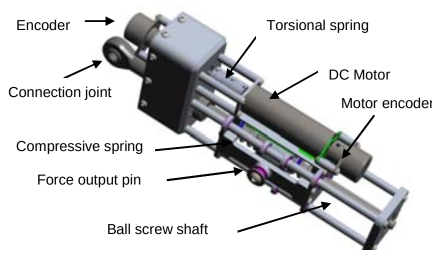

Figure 2. The Novel Compliant Actuator for the Robot.

III. Experimental Validation

A robust force control algorithm has been implemented for the actuator to achieve acurate force control during walking and an impedance control has been implemented for gait trajectory control and tested. We are currently developing more advanced adaptive control for effective gaiting training.

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