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DELIVERING QUALITY SCIENCE TO THE WORLD

A Lower Limb Exoskeleton with Hybrid Actuation

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Abstract: In this paper, the lower limb exoskeleton uses a harmonic drive actuator and two pneumatic artificial muscles (PAMs). This hybrid actuation takes both advantages of harmonic drive and PAM. It provide high accuracy position control and compliant behavior. The disadvantages of each type of actuator are overcome. This exoskeleton is suitable for the strength augmentation of human lower limbs, such as the gait rehabilitation routine of hip and knee joints
Keywords: Limb exoskeleton, PAM, hip and knee joints.

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1. INTRODUCTION

The exoskeleton is a type of device designed to be used as a garment on the body, such as a trouser or jacket, as described in the term "wearable robot." This robot can be used as a tool to partially enhance or replace the musculoskeletal system because certain types of injuries are neurological and neuromuscular diseases such as hematopoiesis or muscle atrophy, muscle degeneration or old age. In the literature, we found that the initial development was mainly focused on strength enhancement, mainly the military DARPA exoskeleton project. These developments provide valuable information for mechanical structures and electronic realization theories. One of the most important developments is BLEEX (Berkeley Lower Extremity Exoskeleton). Designed to enhance the strength of the lower extremities to help withstand the high loads driven by pneumatic actuators, powering the entire leg (hip, knee and ankle). Other exoskeletons sponsored for the DARPA project are Sarcos Exoskeleton and the MIT Exoskeleton. Many other non-military projects have proposed many other alternatives to enhance human capabilities. The latest version of is an exoskeleton that uses a DC motor to connect the harmonic drive gear to power the hip and knee joints. The robot is equipped with an EMG sensor to monitor muscle activity to drive the joint. In two developments of the same lower in vitro bone with 10 degrees of freedom were proposed, driven by pneumatic muscles to drive the hip, knee and ankle joints, one for strength enhancement and the other for active assistance. Walking training.

2. LOWER LIMB EXOSKELETON

We propose a pseudo-personal structure with four degrees of freedom. The exoskeleton powers the active buckling/stretching freedom of the hip and knee joints by a hybrid pneumatic-electric system consisting of a harmonic-driven actuator placed directly on the joint and with a Bowden cable-based drive The device combines to have an antagonistic configuration of two pneumatic muscles. Ankle flexion/extension freedom is passive. The hip joint has 3 degrees of freedom; the abduction/adduction and inner/outer rotation are passive and the flexion/extension is active. The knee has a passive degree of freedom for abduction/adduction movement. The structure of the exoskeleton consists mainly of the nylamid of the joint part and is machined using a CNC machine. The adjustable elements of the outer skeleton are connected by aluminum strips and tubes. Adjustable elements for the upper and lower legs include spring dampers to reduce the effects of collisions in the operator's limbs. These components can be easily and quickly adjusted as needed and can be changed to a length of 100mm. see picture 1.

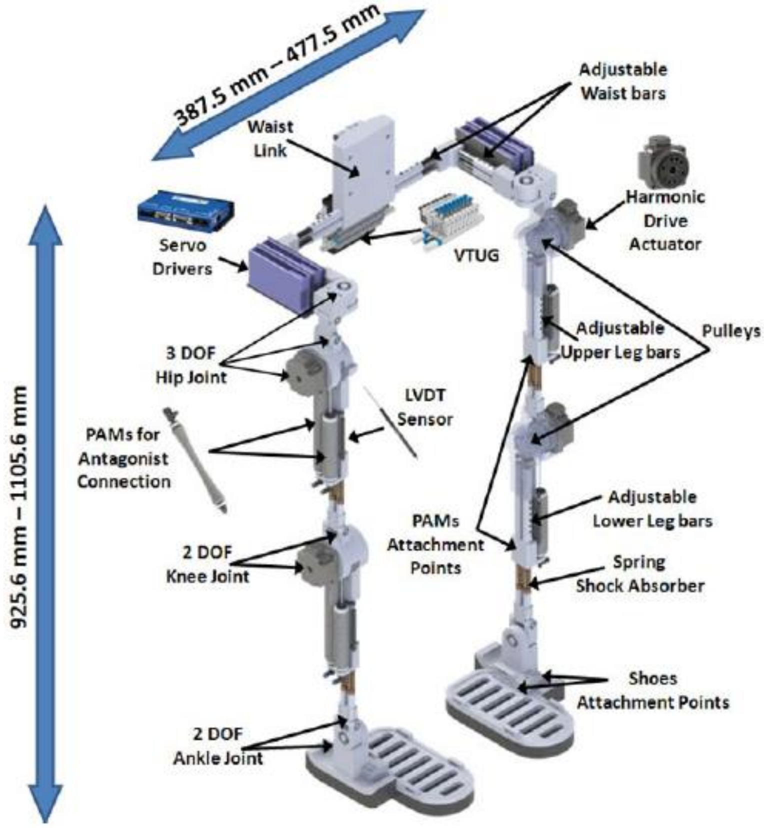

Figure 1. The 3D CAD

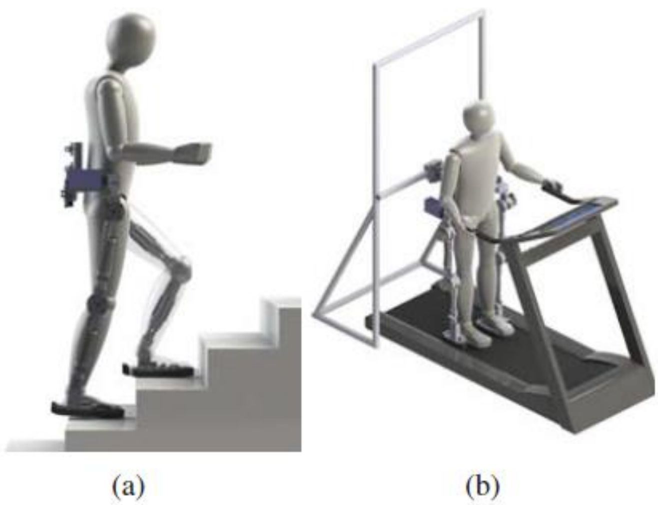

Figure 2. Construction of an exoskeleton for a variety of purposes

The exoskeleton is designed to enhance the enhanced exoskeleton, as shown in Figure 2a, as an exoskeleton for active gait rehabilitation using a treadmill, as shown in Figure 2b. Many commercial devices do not allow configuration changes to be used in other activities, which reduces the use of their features. Therefore, our advice allows for changes from one activity to another without major changes. In order to achieve this goal, we have designed a lumbar connection that can easily connect the fixed structure to work together as a gait trainer as shown in the figure. Similarly, the component can be connected to a battery and air source device. Supply enhanced exoskeleton.

3. HYBRID ACTUATOR

Active compliance control is also force control. Force control of the robot manipulator is to control the interaction between the robot and the environment. This control measures and controls the contact force applied to the arm, thereby greatly improving the effective working accuracy of the robot.

With the increasing use of robots in various fields, many occasions require robots to have the ability to sense and control contact forces. For welding, handling, and painting, the robot only needs position control, and for cutting, polishing, and assembly operations, active compliance control is required. For example, in the precise assembly of the robot, the surface of the workpiece, the grinding and scrubbing, etc., it is required to keep the end effector in contact with the environment. Therefore, the robot must have such active force feedback based on the completion of these tasks. The ability to control softly.

We propose a hybrid pneumatic-electric system to power the exoskeleton joints. The goal is to combine the two types of power supplies to provide the advantages of the device for each type of actuator. On the one hand, harmonically driven actuators have high torque, high precision position and relatively small size. This feature is very suitable for gait rehabilitation, where repetition factors in the gait cycle are very important for promoting and accelerating rehabilitation. On the other hand, pneumatic muscle actuators (PAMs) are lightweight and have high power/weight and power/volume ratios compared to all existing actuators, and also have inherent resilience (compliance) that can be used to provide compliance Sexual actuation, especially when due to neurological diseases or other causes, can lead to involuntary muscle contraction in patients.

Then, with this feature, we propose a hybrid actuator to provide high-precision position and compliance actuation for the joints of the exoskeleton. The rotating joint is designed for sagittal plane movement of the hip and knee joints, as shown in Figure 3. First, the harmonic drive actuator is mounted on the nylamid machined part, and the mechanical stop limits the range of motion on the base of the Table I. The double-slot pulley is used to construct a Bowden cable-based transmission, driven by two PAMs, with a Bowden cable attached to the top of each muscle, which is attached to the bottom of the adjustable exoskeleton link end. The two mechanisms are connected by six setscrews to secure the pulley to the shaft of the harmonic drive actuator.

The implementation of the pneumatic setting is the same as explained in . The PAM is driven by a set of electronic components that are combined in a valve terminal that is fixed at the lumbar link, each muscle including an LVDT linear motion sensor and a pressure sensor for position sensing. Muscle diameter is 30 mm, contraction length is 210 mm, maximum length is 290 mm.

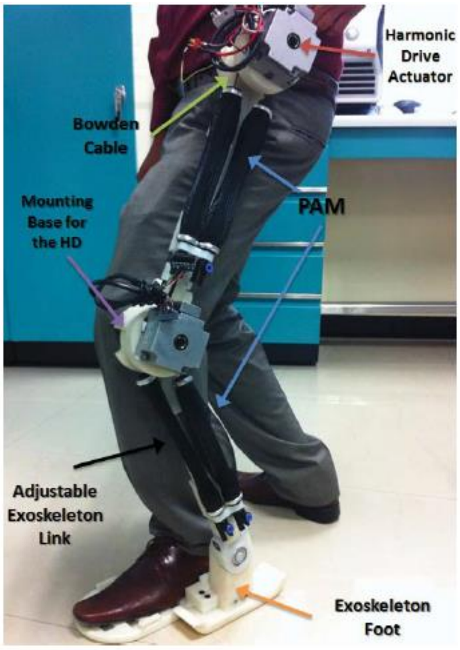

Figure 3. Exoskeleton and joint components are currently being built

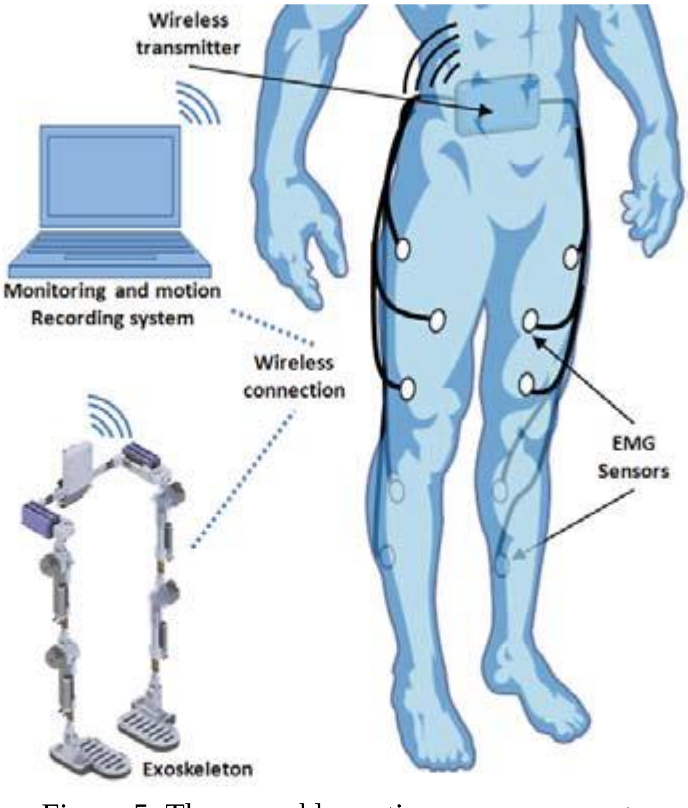

Figure 5. The wearable motion sensor concept

4. WEARABLE MOTION SENSOR

The system design concept is shown in Figure 4. The goal is to use wearable motion sensors as a tool to capture lower limb motion from different test subjects and to generate a basis for gait patterns for the simulation level of the prototype design control rules, and also to develop exoskeleton controlled by EMG signals. The myoelectric signal is recorded on the lower limbs. The muscles measured were the left and the gastrocnemius (each leg), used to measure the motion of the hip and knee joints. Corresponding EMG signals are amplified and filtered accordingly to obtain an estimate of the angular position and angular velocity in the sagittal plane of each joint. The goal is to use this mode of activation of the muscle fibers to predict the operator's intention to move the legs, and then the exoskeleton can detect these signals and begin to move to match the movement of the operator's legs. The EMG signal will be transmitted over a wireless connection, which is designed to increase the efficiency of the exoskeleton, allowing harmonic motion to enhance the healing process.

5. CONCLUSION

In this paper, we present a novel design of the lower extremity exoskeleton for a variety of purposes. We combine two different types of actuators to balance both. The high pressure of PAM produces tremendous power. Since PAMs in antagonist devices provide compliance control, they are ideal for force-enhancing portions of the exoskeleton. Harmonic drive actuators have high positional accuracy and relatively small dimensions. These attributes meet the requirements of a periodic rehabilitation program. The prototype is still in production. We will use it to test different rehabilitation work for wearable motion sensors.

REFERENCES

[1] Zhang Lijian, Yi Wangmin, Wan Bile, Meng Shaohua, Hu Ruiqin. Multi-pin hole assembly force compliance control of space robot based on dynamic feed forward [J]. Journal of Mechanical Engineering: 1-10.

[2] Wu Dongjie, Zhao Zhen. Research on Robot Force Control Research[J]. Mechanical Engineering and Automation, 2018(02): 223-224.

[3] Wang Junzheng, He Yudong, Wang Shoukun, Zhao Jiangbo. Master/passive compliance control of hydraulic foot robot based on force feedback [J]. Journal of Mechanical Engineering, 2017, 53(01): 13-20.

[4] Zhu Jianying, Zhai Zhongxin. A Review of Research on Robot Force Control [J]. Journal of Nanjing University of Aeronautics and Astronautics, 1997(02): 100-110.

[5] Yany Zong-quan, CHEN Xin-du, WU Lei. Research on Robot Force/Position Control Strategy Based on Fuzzy Compensation[J]. Machine Tool & Hydraulics,2017,45(17):1-5.

[6] Yang Lin, Zhao Jibin, Li Zheng, Liu Lei. Research on force control of plexiglass grinding and polishing robot[J]. Mechanical Design & Manufacturing, 2015(04): 105-107+111.