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Human Body Exoskeletons for Performance Augmentation & Rehabilitation

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ABSTRACT: From the early 1960s the development of the human body exoskeleton has been progressing. There are lots of variation has been made to assist the user's movement. Leg exoskeletons are comparatively simpler to design than upper-limb exoskeleton, but still have particular physical requirements from the co-ordination of human and robot. In the field of the art, different control strategies and approaches can be simplerly found: it is still a challenge to produce a supportive strategy which makes the exoskeleton supply efficient. So, this aims to provide a methodical overview of the assistive strategies utilized by operative locomotion-augmentation orthoses and exoskeletons. Which based on the information collected from Web of Science, we have studied the main robotic gadgets with a focus on the path they are controlled to deliver assistance; the pertinent validations are as well investigated, in particular experiments with human in the cycle. Finally current trends and big challenges in the development of a supportive strategy are concluded and discussed

KEYWORDS: lower body exoskeleton, wearable, powered, assistive robotic, passive.

I. INTRODUCTION

According to UN population percentage statistics, the number of people above the age 60 will rise constantly to about 1 billion in 2050. [8] These 1 billion will include healthy persons and also people affected from heart diseases, spinal cord injuries and other problems which will hind their normal mobility. People in this age tend to lose their freedom and have to depend on others for their basic requirements. Currently, gadgets like crutches and wheelchairs have been used to support in personal in rehabilitation applications but these gadgets are not much effective. They could not solve natural problems faced during the use of these gadgets even if the people do not use the gadgets but employ an assistant or a family member for helping them.

The major problems faced by aged people are:

- Unable to sit, stand, perform transfers and to walk,
- required personal assistance at home,
- risk losing freedom.

A number of individual transportation treatment approaches have been proposed to enhance overall walking ability. The healing process to regain lost flexibility capability is more effective between the first 3 to 6 months and after the stroke onset and it is mostly dependent on the individual. At this point, intercession programs can be started to retrain the ability to produce strong movements and work trajectories while performing activities of daily life. The most important task is to be relearned, as claimed by patients passing through stroke, is the possibility to walk again, in order to regain normal life when possible. Task oriented and mostly repetitive practice motions are identified as interventions

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for the restoration of gait function. [2] Such robotic equipment for gait training and it can be divided into two groups as: end effectors and powered exoskeletons. The term exoskeleton coming from the Greek words “exo” = outer and “skeletos” = skeleton, is an external structure that supports and protects an animal’s/human’s body, in contrast to the internal skeleton of, for example, a human.

CLASSIFICATION

According to the Merriam-Webster dictionary, an exoskeleton is ‘an artificial external supporting structure’. It closely fits the body of the wearer. Here we will deal with powered exoskeletons starting from the first exoskeleton realized to the latest ones. In this section, a state-of-the-art review on exoskeleton devices is presented. The major focus of the exoskeletons realized to date is on lower limb exoskeletons for paraplegics and elderly persons. There are basically two types of exoskeleton: powered exoskeleton and passive exoskeleton. [10]

POWERED EXOSKELETON: As the name suggests power means it required external power supply to perform work. It does not require any human effect. The main function of powered exoskeleton is to do jobs which are not humanly possible, but it is big and heavy and requires large space. BLEEX, SARCOS, REWALK are some of the powered exoskeleton.

PASSIVE EXOSKELETON: It does not require any external power supply to perform task. Hence it is totally work on human efforts. The main advantage of this exoskeleton is portable and light in weight. The wearable chair is one of the example of passive exoskeleton.

II. EXOSKELETONS IN USE

A. BERKELEY LOWER EXTREMITY EXOSKELETON (BLEEX)

It is the first load-carrying and energetically autonomous exoskeleton. With a humanoid design, BLEEX has a left and right three-segment leg, being similar to the human thigh, shank and foot. Each leg has seven degrees of freedom. The work has presented an assistive strategy for BLEEX based on sensitivity amplification controllers. In this work, the inverse dynamics of BLEEX in sagittal plane is modeled differently depending on three gait phases: a full 7-DOF serial link mechanism for the single-support phase; two 3-DOF serial link mechanisms with one connection DOF along their uppermost link for the double-support phase; a 3-DOF serial link mechanism for the support leg and a 4-DOF mechanism for the redundant leg during late stance phase. The gait phases are distinguished by foot insole sensors. [1] Under this control strategy, the user, wearing BLEEX, could walk at an average speed of 1.3 m/s while carrying a 34 kg payload. In recent years, military-used strength augmentation exoskeletons have been developed prosperously and reached or been near to market application, for example, the Sarcos-Raytheon ‘XoS’ series and Human Universal Load Carrier (HULC). However, they are available only on media platforms without public scientific research results. As these devices are structurally similar to BLEEX, the sensitivity amplification control is as well supposed to be suitable for these devices. [7]

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Fig. 1 BLEEX[7]

B. SARCOS EXOSKELETON

This is a powered exoskeleton which provides Autonomous power supply to the user. It has rotary hydraulic Actuators and uses force sensing to control the motion. The Wearer cannot bend his feet due to a metal plate that is installed behind it which includes force sensing elements. This is a very powerful suit as shown in figure targeted for military purposes. The exoskeleton uses a variety of sensors for determining force and position of the system. [3] The sensors are linked via wires to distributed computer processors in each joint, which allow the actuators to deliver up to 200 kg per square centimeter of force through high-pressure hydraulics immediately.



Fig. 2 Sarcos Exoskeleton [3]

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C. WEARABLE CHAIR

Wearable chair is a passive kind of exoskeleton. It is similar to a light weight mobile exoskeleton that assist people to sit anywhere in any working position. The normal chair is difficult to drag to different working locations due to its large size, heavy weight (~5 - 6 kg) and rigid structure and thus, they are not suitable for workplaces where sufficient space is not available.[6] It has a gross weight of 3 kg as it utilizes light-weight aluminum alloy members. Unlike the normal chair, it consists of kinematic pairs which enable taking pause between continuous movements at any working position and thus, it is capable of reducing the risk of the physical musculoskeletal disorder substantially among workers. The objective of this paper is to focus on the mechanical design and finite element analysis (FEA) of the mechanism using ANSYS software. In the current situation, all the parts of the mechanism are designed under static load condition.[5] The outcomes from the analysis indicate that wearable chair satisfies stability criterion and it holds capability of decreasing fatigue during working in an assembly line or factory.[9]



Fig. 3 Wearable Chair [4]

D. REWALK

ReWalk is a powered exoskeleton to assist individuals with thoracic-level complete SCI to walk independently. Its hip and knee joints are powered and controlled to follow a predefined trajectory. With a wrist-pad controller, the user can activate the robotics system to perform stand, sit or start walking; with a torso tilt sensor, the user can trigger step to step transition during walking. [11] Twelve subjects with chronic motor complete cervical and thoracic SCI have been trained to work ReWalkTM. After eight weeks of practicing, all subjects were able to walk with freedom by crutches, without any other human help, for at least 50 m continuously, for a period of at least 5 to 10 minutes continuously and with speed ranging from 0.03 m/s to 0.45 meter per second.[12] Their gaits were basically symmetric.

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Fig. 4 Rewalk [7]

III. CONCLUSIONS

We believe that, the future of assistive exoskeletons is bright and such devices are widely predicted to be in high demand to meet the needs of the global ageing society. In this paper, we have reviewed various kinds of assistive strategies employed in powered exoskeletons for the selected literature. Generally, an assistive strategy has to deal with two main issues regarding the user-exoskeleton mutual interactions: a physical interaction, i.e. the mechanical power transfer, and a cognitive of controller (position, velocity or torque control) –, the cognitive interaction depends on the high level controller, i.e. the global assistive strategy, which we aimed to explore and compile in this paper. Hence exoskeleton is a milestone and it is helping mankind forward into the future

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