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A Study of Design and Implementation Techniques of Active Soft Orthotic Ankle Foot

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Abstract

This paper reports on the mechanical design of an active soft orthotic implementation for AFP, which is powered by the pneumatic artificial muscles. Ankle foot orthosis makes a neuromuscular patient's having gait pattern more rehabilitate like that of an unaffected person, but the devices can also be associated with compensations of their own. And some patients with a normal gate pattern are not necessary for its functionality. In this paper our study focuses on the rehabilitation performance based on the ankle foot orthotic device.

Keywords

Orthotics, Ankle foot orthosis, neuromuscular model

1. Introduction

The main issue of this research is to provide the rehabilitation in patients with neuromuscular disorders such as hemiplegia, spinal cord injury (SCI), cerebral palsy (CP), multiple sclerosis (MS) [1] [2], and muscular dystrophy may create compensatory gait pattern in the patients, and interventions as a physical therapy and bracing with ankle-foot orthotic device (AFOD) helps to normalize the gait pattern. As we consider dropping foot one example. Which due to the damage of the long nerves of brain or spinal cord, the lower leg anterior muscles become weaker when the muscles are become stiffer on the posterior side? Thus the dropping foot in swing phases causing toe strikes instead of heel strikes, which sometimes results in trip and fall. The alternative for drop foot using ankle-foot orthotic device (AFOD) has the potential not only for preventing the development of abnormal gaits over time but also for providing immediate assistance in walking. The main advantage of the AFOD is that the waling action analysis and determination of the sensor places are observed. But the data of information which generated through the experiment which is not work for a long time.

The actuation of gait rehabilitation using an actuated orthosis can substantially improve the training by providing a steady and accurate leg motion and by relieving the therapist from heavy physical strains. The orthosis is intended as a proof of concept rehabilitation device for the mechatronical design principles assessment and testing of various control strategies. The process mainly focuses on the concept of fitting and a special attention has been paid to the adjustability of the device. Also safety mechatronical measures were to be added in order to ensure a safe operation of the device [3].The ankle-foot orthotic devices (AFODs) are devices are often prescribed to improve gait performance for persons with impaired lower leg function as assistive devices. The design may vary in shape, size, and functional characteristics depending on the desired clinical applications. So, the classification of an active dynamic orthotic device contains those devices that use motors, pumps and actuators to actively control the magnitude of joint assistance and level of mechanical energy transferred[4].Thus, a fundamental criterion for selecting the most appropriate material for AFOD fabrication is minimizing energy dissipation through internal friction during AFOD deformation .

2. Literature Review

The control strategies and the assessment of mechanical concepts actuated by the pleated pneumatic artificial muscles is the proof for the active knee rehabilitation. The special attention is given towards fitting and the concept of adjustability.

A. Experimental Setup

In 2010 Kyung Kim, Jae-Jun Kim et al. [5] [7] proposed that the experimental setup was used for elderly people and young adults. The EMG signals were used to measure the muscles physiological changes.

As all the procedural experiments and the statistical analysis were performed by using SPSS (v.12), which would calculate the mean and standard deviation. The comparison was made for differences in EMG parameter during Squat exercise and the extension torque of knee joint using a paired t-teat was performed. The various tests were performed to changes the differences in the above test results. The primary objective of an ankle-foot orthosis is to restore the rehabilitation function of the amputated knee and ankle joints. These benefits should reduce back and hip pain and should improve mobility to afford the patient a healthier life. By adding the compliant joints and segmented foot to bio-inspired below-knee exoskeleton prevents the human normal walking gaits .A below knee exoskeleton prototype with ankle and toe joints driven by two series-elastic actuators. This system measures the effectiveness of the developed ankle-foot orthosis with feed-forward control.

B. Exoskeleton Prototype

In 2011, Jinying Zhu, Qining Wang et al. [6] [7] proposed that the exoskeleton prototype (EXO-PANTOE) with complaint joints and segmented foot. It was designed for a subject subjecting from some ankle pathology with two SEAs. Each SEA comprises a ball screw transmission and a spring structure with DC motor. The EXO-PANTOE ankle joint can be simplified by a rotating guide bar mechanism comprises with three bars. The proposed system with adding complement joints and segmented feet has passively-based bipedal model and related analysis are as follows:

1. Human Normal Walking Gaits

A cyclic pattern of human walking is a bodily movement with step after step and repeated over and over. Each of the cyclic patterns can be divided into two main phases: stance phase and swing phase

2. Passivity-based Bipedal Model

In this section, a passivity-based dynamic bipedal walking model proposed that is more close to human beings. The passive walker travels on a flat slope with a small downhill angle.

3. Walking dynamics

The walking velocity was used to measure the efficiency, such that "most efficient" or "fastest". It improved the energetic efficiency and walking stability. The two experiments are conducted to (1) to show the influence of toes by comparing walking with an without AFO, and (2) clarify the functions of toe during walking by correlating activity of the major muscles controlling the ankle and the toes to shoe sole pressure data during walking. These two experimental results analyze the necessary components and conditions of an ankle-foot model for developing an AFOD. The functional performance of AFOs has been quantified with time and distance measures, such as walking velocity, cadence, step length, stride length and cycle timing. Time and distance measures along with leg joint kinematic and kinetics are used for quantify portable powered ankle-foot orthosis performance. The straight design requirements of light weight, small size, high efficiency and low noise make the creation of a daily wear assist devices challenging. The result shown by the powered exoskeleton prototype can be well assist the subject to relearn the normal walking gaits and the segmented foot structure can well decrease the total energy cost of EXO-PANTOE 1.

C. PPAFO Methods

In 2011, Kenneth A. Shorter, Yifan Li et al.[8] proposed that the PPAFO method, used carbon composite shank and foot pieces, which actuated by a rotary actuator at the ankle joint powered by portable pneumatic power supply. The device provides a triggered assistance in three regions determined by functional gait requirements: (1) dorsiflexior to prevent foot slap during loading response by foot motion controlling, (2) plantar flexor torque, which is used to provide assistance for propulsion during stance, and (3) dorsiflexior torque to prevent foot drop by maintaining toe clearance during walking.

The PPAFO has used force sensor on foot plate to detect the event boundaries of the three regions. Also the various results were detected when sensor magnitudes exceed tuned thresholds for metatarsal sensors and for the heel. The main advantage of the PRAFO is that it is capable of providing functional assistance but control of the system not well improved.

In 2012, US.M.H.Sithi Shameem Fathima et al.[9] proposed that system As a part of walking assistance and rehabilitation for the disabled people, an AFOD plays an important role which enable patients to resume their normal social activities at an earlier time. S. Fathima and R. Banu proposed an intelligent authentication of a human by using various feature extraction. In this scenario Biometrics and Pattern recognition both the emerging technology combines with Human gait recognition. The reason for using Human gait recognition for identifying the person with his walking style alone without getting other information like voice, environment etc. The author uses the CASIA database algorithm for human gait recognition which shows the following Recognition rate.

Table1: Recognition Rate

Sr. No.	Algorithm	Dimensions	
1.	Data Base	5ANGLES	6ANGLES
2.	CASIA	83.332	93.2

The biometric and pattern recognition are the emerging trend in the present scenario. Human gait recognition which combines both the technology. By using surveillance camera with walking style of an individual can be captured. By analyzing the walking dynamics like gait cycle, ankle width, knee stride width, ankle elevation feature subset selection like knee rotation , hip rotation, ankle rotation mark etc.

In 2011, Kurtuluş Erinç Akdoğan, Atila Yılmaz et al. [10] proposed that the microcontroller based realization of gait speed estimation for electronic above knee prostheses was presented by K. Akdogan, A. Yilmaz et al presented a low cost system for two dimensional gait analysis in the sagittal plane have been equipped for testing the performances prosthesis and developing the control unit sensing the user intentions and various control conditions. Due to low cost and 'easy to use' structures for prosthesis a gyroscope and accelerometer among standard sensors were selected. For these two sensors the speed estimation algorithms are develops and they uses in microcontroller based control unit of artificial knee.

The experimental evolution of a Portable Powered Ankle-Foot Orthosis (PPAFO) which provide both plantarflexor and dorsiflexor torque assistance through a bi-directional pneumatic rotary actuator. The complete system uses an embedded electronics and a portable pneumatic power source (bottle of compressed CO2) to control foot action during walking. In this study, the PPAFO is used not only to provide functional assistance to control the foot during stance and swing but also measures time and distance along with leg joint to improve the PAFO performance. The proposed system is lightweight, compact and is capable of providing untethered functional assistance for impaired walkers.

In 2011, Kuehn, Felix Grimminger, Frank Beinersdorf proposed that the the additional DOFs and Sensors for Bio-Inspired Locomotion system which contributes towards the active spine, ankle joints, and feet for a quadruped robot. The proposed system should effectively improve the mobility and locomotion with the design of biologically inspired structural components. The system completed with the 49 pressure sensors, a 6 DFOs force/torque sensor, absolute position sensor as well as temperature and distance sensors which allow the precise perception of the environment. In this literature effective gait recognition pattern is well obtained and one drawback of the system is that discontinuity present in the silhouettes.

In 2011, Takehito Kikuchi, Toshimasa Tanaka et al.[12] proposed the system to provide control the advanced composites used in that device permit some energy storage during controlled dorsiflexion and plantar flexion, and subsequent energy release during powered plantar flexion, in the intact human. They also studied the highlights the importance of neuromuscular controller for enhancing the adaptiveness of powered prosthetic devices across varied terrain surface. In another report, we discovered a fact that a gait measurement system to establish control models for the intelligently controllable ankle-foot orthosis (i-AFO). They also discovered 4 phases to classify each part of the gait cycle as shown below (fig.1).Here the need of highly integrated structure processing of sensors information is shown.

Phase1: Duration from initial contact (IC) to foot flat (FF),
Phase2: Duration from FF to heel off (HO),
Phase3: Duration from HO to toe off (TO),
Phase4: Swing phase (from TO to the next IC).

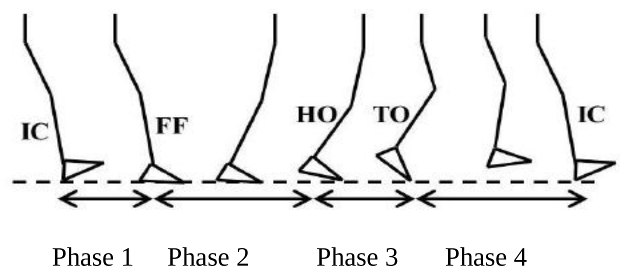
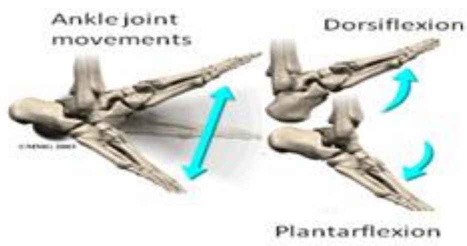


Fig.1: Gait cycle of healthy person and definition of each phase

They shows that the experimental result includes periods of initial contact to foot that don't correlate with the walking speed. In addition the patients having a dysfunction of the ankle, means that the patients suffering from polio or peripheral nerve palsy, have more difficulties in controlling their ankle movements (shown fig.2). The ankle joint is a hinge that allows the foot to move up (dorsiflexion) and down (plantar flexion). The ankle joint is a synovial joint, meaning that it is enclosed in a joint capsule that contains a lubricant called synovial fluid.



(a) Bone Movements

(b) Dorsiflexion **(c) Plantar flexion**

Fig.2. (a): Bone Movements (b) Dorsiflexion and (c) plantar flexion of ankle joint

Anterior impingement may feel like ankle pain that continues long after an ankle strain. The ankle joint may feel weak, like it can't be trusted to hold steady during routine activities. Even when anterior impingement comes from ligament irritation, tissue thickening and pain are usually felt in front and slightly to the side of the ankle. This is the area of the AFTL. The pain worsens as the foot is forced upward into dorsiflexion. If the ligaments have irritated are synoviam of the ankle joint capsule, swelling and throbbing pain from inflammation (synovitis) may also be felt in this area.

This causes "drop foot" or a lack of dorsiflexion of the ankle during the swing phase. Sometimes such patients are unable to prevent themselves from catching their toes on the ground and stumbling, even when taking small steps. In other way, these patients tend to incline their bodies more than do healthy persons because of the motion required to prevent stumbling.

There are five basic types of AFOs that we can choose for our patients with drop foot:

- Short leg fixed AFOs
- Dorsiflexion assist short leg AFOs
- Solid ankle AFO (with or without posterior stop). Also available with dorsiflexion assist.
- Full leg posterior leaf spring AFO
- Energy returns AFOs [13].

3. Conclusion

In this paper, we studied the different existing system approaches in order to provide the human gait assistance focuses on the ankle-foot joints. The various techniques have been used to improve locomotion and mobility while dropping the foot. Some of the existing techniques are inexpensive but having much bulky and not surely specified the restricting angle while sitting.

Thus, In order to overcome the above disabilities or orthotic design, we will develop a system which is more comfortable without restricting angle while sitting. The prototype will be flexible and awareness with the gait pathologies disorders by using pneumatic artificial muscles and different types of sensors.

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