Intelligent Assistive Device to Monitor

Ankle-Foot Orthosis

Department of Information Technology, Kumaraguru College of Technology,
Coimbatore, Tamil Nadu, India

Abstract - Active Ankle foot orthosis is used to compensate for muscle weakness, called Drop Foot caused by stroke, spinal cord injury, multiple sclerosis or any gait pathologies associated with neuromuscular disorders. People with drop foot need assistance in taking a step since the movement is impaired due to weakening and stiffening of muscles in different portions of the leg. This paper describes a system for actuating a drop foot using electric stimulation for muscles when the disorder is acute. The position of foot is sensed and used as a feedback to controller to make a decision on whether actuation is required. The device also alerts the care taker of the patient through mobile device connected through Bluetooth and generates a progress report. A laboratory model of the proposed system was implemented. The control device can be used in several applications involving control of different types of orthoses used for gait correction.

Keywords: Ankle foot orthosis, drop foot, electric stimulation, passive and active AFO, semiactive AFO.

1 Introduction

Abnormal gaits are seen in patients with neuromuscular disorders, such as stroke, cerebral palsy (CP), amyotrophic lateral sclerosis (ALS), or multiple sclerosis (MS), where pathologies of the ankle-foot present an everyday problem, particularly over a period of time. Drop foot is one example. This is because, due to the damage of the long nerves or of the brain or spinal cord, there is uneven spread of reflexes over the different muscles of the leg. The anterior muscles of the lower leg which work for dorsiflexion become weaker while the posterior muscles become stiffer. The result of this is a drop foot. The obvious result of this disorder is the tripping and falling of the patient due to the fact that the foot drops in swing phases causing toe strikes instead of heel strikes.

This has to be treated in two phases: The first and foremost is to provide walking assistance to the patient through artificial means. The second phase is a prolonged benefit where the development of abnormal gaits can be prevented over time. Though much research has gone on in providing assistance to drop foots both in the way of physical assistance as well as providing a confidence to the patient, most widely used solution is to wear a passive orthotic device, such as an ankle-foot orthosis (AFO), which forces the joint angle to be close to 90° [2].

1.1 Ankle Foot Orthoses

AFOs are of many types. It is most commonly classified as passive, semi-active, and active. Passive devices are the static devices which do not have any electronics in them but they may have mechanical elements such as springs or dampers, which enable motion control of the ankle joint during gait. These devices have no automation in sensing or responding. Semi-active AFOs are the ones using computer to control variance in compliance or damping of the joint in real-time. Here the control can be automated but the monitoring is done manually. Fully active AFOs are meant to have onboard or tethered sources of power, one or more actuators to move the joint, sensors, and a computer or onboard electronics used to control the application of assistance during gait.

Active ankle-foot orthoses (AAFOs) are orthotic devices intended to assist or to restore the motions of the ankle-foot complex and are based on force-controlled actuator [1].

These devices are more concentrated on the actuation of the affected limb and these devices have been developed to assist the patient but the progress of the patient is not monitored. They are not focused on long term assessment. When the device is simply mounted on patient to make the limb move, it does not mean that the patient will recover. There is a need to monitor the patient continuously and motivate them by showing them their progress.

Laboratory monitoring is usually implemented in fully active AFOs. But the monitoring is done by connecting the device to the computer. This makes the device non portable. In order to make the device portable with real time monitoring, we need to establish wireless communication between the device and the monitoring system. In this case we cannot make the...
monitoring device to be at one place. We need to make the monitoring device also portable.

1.2 Android Device Monitoring

Android is the most powerful mobile operating system, which is used in most of the mobile devices now-a-days. It has wide range of interfacing facilities in it to communicate with other embedded devices. But using the android operating system and be able to get information on the condition of a patient from a long distance will keep the family happier.

2 Literature survey:

Veneva I[2010] developed an autonomous adaptive system for actuation, data processing and control of active ankle-foot orthosis. This system is composed of control system with actuation by sensing the improper foot position and viewing the results on a separate GUI display for monitoring. This system is just for laboratory monitoring with a graphical program written in MATLAB. The system cannot be used for continuous monitoring [1]. Yong-Lae Park et al [2011] have created the design of an active soft ankle foot orthotic device powered by pneumatic artificial muscles for treating gait pathologies associated with neuromuscular disorders. The design is inspired by the biological musculoskeletal system of a human foot and a lower leg, and mimics the muscle-tendon-ligament structure. A key feature of the device is that it is fabricated with flexible and soft materials that provide assistance without restricting degrees of freedom at the ankle joint. But the system is too heavy to mount on the patient [2].

Blaya and Herr [2004] developed an adaptive control system for ankle foot orthosis. They used a serious elastic actuator and ankle angle sensor which is a circular potentiometer to detect the angle by resistance encountered. They applied variable-impedance on the adaptive basis by using computer controlled AFO. In this system importance for continuous monitoring is not given [3]. Kenneth Alex Shorter et al. [2013] have done study on Technologies for Powered Ankle-Foot Orthotic Systems. They made a complete comparison of strategies about all AFOs, on powering, structure and efficiency of the AFOs that are currently available on the field [4].

3 Method

The active ankle-foot orthoses has three basic components: Electro-Mechanical, Control and Alerting and report generation unit. The Control Unit receives values of the ankle’s angle and toe clearance from sensors (Flex sensor to detect the angle and pressure sensor to detect the toe clearance). By receiving the values from the sensors, the arduino microcontroller generates the flexion/extension motions and controls the Electro-Mechanical Unit.

3.1 Electro-Mechanical Unit

Electro-Mechanical Unit consists of the Actuator which actuates the leg to the normal position whenever it detects a drop foot condition on the leg. The flex sensor is placed on the top of the leg across the ankle as shown in figure 1. The pressure sensors will be placed inside the insole as shown in figure 2. The actuator does not affect the normal leg movement. It actuates the leg only on the condition of drop-foot.

3.2 Alerting and Report generation Unit

Alerting and Report generation unit is a separate device which is powered by android.
3.3 Control Unit

The control unit sends the leg position to that device. The device is meant to be with care taker. The device alerts the care taker in case of any instability found during gait. It also records the situations of instability of the patient. It stores data as number of times the patient faced instability condition in the day. A weekly report will be generated on the device and it is sent to the respective doctor.

4 System Design

The complete autonomous system consists of four primary components - sensing, data processing, actuation and alerting and report generation.

The sensor system has been mounted onto two basic components: insole with pressure sensor and flex sensor for ankle angle detection. During walking, the processing unit gathers and digitizes the information from the sensors. In monitoring mode these data are transferred through the Bluetooth to android mobile device for alerting and report generation.

The system power source is an important part of the project. Three separate power sources are required. One is to power arduino, second is for the actuation part and next is for Bluetooth module.

4.1 Sensing Unit

Sensing unit consists of three sensors. Two pressure sensors are used for toe clearance and one flex sensor for ankle’s angle detection. Two pressure sensors will be embedded inside the insole. The flex sensor will be placed above the ankle with the help of socks. The pressure sensors gives value depending on the pressure/force applied on it. We need to map the values according to our need. We have setup a threshold value above which we detect the toe on ground state.

Same as the pressure sensor, the flex sensor values have to be mapped in order to get the ankle’s angle.

4.2 Data Processing Unit

Data Processing Unit consists of the arduino UNO which is microcontroller featuring basic hardware peripherals such as Analog to Digital Converter (ADC), serial communication to connect with Bluetooth and PWM (Pulse Width Modulation) signal to drive motor according to input signal. All the sensors will be connected to the analog input pins of arduino. The arduino converts the analog signal into digital signal to process it.

The condition for actuation and alerting is that the ankle must be leaned in such a manner it becomes 180° and the toe must be on the ground. When the foot is dropped, the system should actuate the leg to normal position. Servo motors are used for the part of actuation of leg. When the foot drops to the improper position, the system automatically actuates the ankle to move the foot to normal position.

Improper condition is found by the three sensors namely S1, S2 and F1. The two pressure...
4.3 Actuation Unit

Actuation unit consists of the servo motors. The servo motors have the torque of 60KG in normal conditions. If the person is heavier than 60KG then we need to opt for higher torque servos. When the drop foot condition is met, the servo rotates back to the normal position (90°) thus actuating the foot to normal position. The servos will be fixed near the ankle.

4.4 Alerting and report generation Unit

The flex and the pressure sensor values will be sent to the android device which is connected to the Bluetooth transmitter mounted on the leg. The android device processes it and alerts the care taker whenever there is an instance of about to fall or a fall. It also stores the occurrence of instability in the database consistently. It sends a weekly report to the registered medical specialist about the number of occurrences per day on the week through email so as to keep track.

5 Experimental Results

Figure 4 – Flow of Data Processing unit

Figure 5 - Ankle Foot Orthosis with alerting and Monitoring
The device has been tested on two patients affected by cerebral palsy for a week by letting them wearing it. As commonly known, the patient affected by cerebral palsy lacks the ability to walk normally and is prone to fall often. Hence this device has been designed to help them walk normally as any other normal human. There are some situations where they were meant to fall by misplacing their leg but at those situations they have been brought to normal state by the device. Such situations have been saved in the database and the report has been generated. The Graph has also been generated to have instant understanding about the patient’s health condition.

6 Conclusion

The monitoring system attached to the actuating system gives overall progress report on the patient’s condition which shows the continuous improvement of the patient. This device has been designed at the request of and in consultation with the therapists at the Occupational therapy unit of Kovai Medical Centre and Hospital, Coimbatore.

7 References


