Towards Performance Monitoring of an Intelligent Lower Leg Orthosis

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Abstract. An intelligent orthosis for knee and ankle joints functional compensation during walking and daily activities is developed in the frame of the Gait project. Such a device can be worn by patients with an abnormal gait caused by muscle weakness at neurological and muscular diseases, to provide safety and walking pattern improvement, while providing a means for biomechanical monitoring during activities of daily living.

The paper presents the approach towards data monitoring for biomechanical evaluation at different scenarios and for a variety of applications.

Keywords. Gait, patient monitoring, orthosis, wireless, biomechanics

1. Introduction

It is frequent to find during rehabilitation medicine practice patients who present muscular weakness of the lower limb. The percentage of persons suffering from these diseases can oscillate between 0.05% and 1% of the total European population. Aetiology could be very diverse, including neurological and muscular disorders, sequels of trauma, spina bifida, and others. Knee ankle foot orthoses are prescribed to treat these disorders while providing stability and keeping joints at their functional position. Conventional passive lower leg orthoses allow stability during stance but result in unnatural gait patterns: An active solution for compensation of joint disorders associated to muscle weakness during cyclic walking is developed [1], aiming at patients with neuromuscular disease (post polio syndrome), cerebral palsy and cerebrovascular accident.

Common gait analysis techniques (video based systems, force platforms, etc) impose mobility restrictions and in many cases tend to reproduce unnatural conditions due to spatial constraints. Besides, traditionally these techniques have been restricted to the laboratory context and this results in a lack of objective information from patients performance outside a controlled environment. A first stage study [2], which considered feedback from all actors involved in leg orthosis prescription, evaluation and manufacturing, defined a goal: to provide new means for orthosis users monitoring both at the lab and at real world conditions, by incorporation of embedded processing, telemetry and data logging, in order to provide the patient, physicians, orthotists and physical therapists with objective information about the performance with a new generation of intelligent orthoses.

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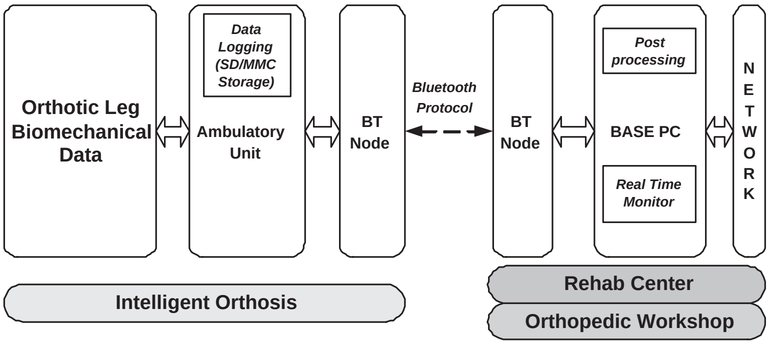

Figure 1. System concept

2. Monitoring System Approach

The technical approach presented in figure 1, is proposed to allow recording and displaying of data about the use of the intelligent orthosis. For this, the ambulatory unit that controls the intelligent orthosis is equipped with a Data Logging unit dedicated to storage in removable Secure Digital Card media and a Bluetooth wireless communication module linked through a serial protocol, for data streaming to a base PC located at the clinic or rehabilitation center.

2.1. Sensor fusion

A high number of sensory signals are combined to allow estimation/extraction of useful parameters related with gait biomechanics, patient/orthosis interface status, rate of use and also, for a posteriori discrimination of activities. Inertial sensing at shank and foot is used to supply basic gait phase detection and joints kinematics [3], in combination with contact sensors at the orthosis insole. Measurement of parameters related to comfort is performed by pressure sensors and strain gages at the pelotte carriers.

2.2. Scenarios

The system is conceived for two modes of operation which involve different applications: real time and off-line monitoring modes. In the real-time mode, data (sampled at 100 Hz) is streamed through the bluetooth link to the base Unit and presented on screen for direct objective feedback to the clinician about the fitting of the orthosis and the most critical biomechanical aspects. During the off-line monitoring mode, which is active during common use by the patient, all data preprocessed by the ambulatory unit is recorded in the SD card -up to 1GB- running at 50 Hz. After this daily process, the information is imported to the base unit, for interpretation and analysis. Within both operation modes the intelligent information that can be extracted from the system is summarized in Table 1.

2.3. Real world data logging

Information collected during the off-line mode is processed in the ambulatory unit under a finite state machine model, which includes rule-based algorithms for detection of the

Table 1. Intelligent Information

Real time	
Knee joint	Status (Feedback to the patient), hinge angle (sagital), Flexion moment(sagital)
Ankle joint	Hinge angle
Interface aspects	Pressure at pelotte carrier, migration of pelotte carriers
Off-line	
Rate of use	Average forces, number of knee bends, time used
Activity monitor	Sitting, standing, walking, stairs and slopes up/down
Gait cycle phases	

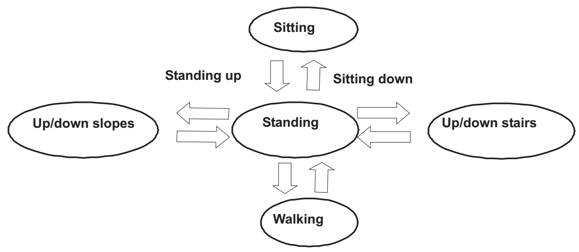

Figure 2. State transitions

different transitions between the possible activities that can be performed with the orthosis (See figure 1). Hence, statistics about rate of use, mean biomechanical figures like knee angle values, peak moments and risk situations, are calculated and presented to the clinician.

2.4. Preliminary results

An example of biomechanical data acquired with the system in the off-line mode is presented in figure 3. Thigh, shank and foot (orthosis) kinematics are measured and calculated based on calibration values. Peak values, zero cross points and correlations between signals constitute some of the criteria for extraction of the intelligent information (gait phases, rate of use, etc).

3. Applications

Although this system has been conceived initially for application on orthoprosthetics, its functionality can be extended to a wide range of applications were human body kinematics and kinetics are to be measured at real world conditions for health monitoring. Currently we explore at IAI-CSIC the application of the developed system, complemented by physiological signals (EMG/EEG), in worksite ergonomics assesment, fall prevention and detection in elderly and sports.

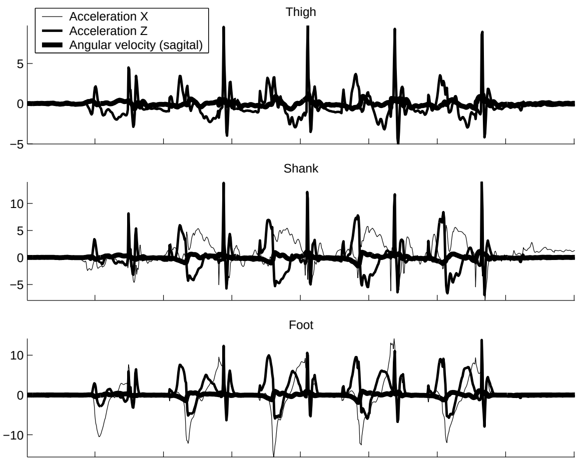

Figure 3. Example of motion data: Segments angular velocities and accelerations during walking

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