Intelligent Knee-ankle-foot orthosis: The GAIT project approach

J. Moreno[1], B. Freriks[2], F. Þorsteinsson[3], J. Sánchez[4], J. Pons[5]

[1]Industrial Automation Institute-IAI. Spanish Council for Scientific Research. Arganda del Rey. Spain
e-mail: moreno@iai.csic.es
[2]Roessingh Research and Development-RRD. Enschede. The Netherlands
[3]Ossur hf. Reykjavick. Iceland.
[4]The Institute of Biomechanics of Valencia-IBV. Valencia. Spain

Introduction. Knee-ankle-foot orthoses are prescribed to provide stability and maintain lower limb joints at their functional position. Current devices provide stability by locking joints permanently during an unsafe phase of a pathological gait (the stance phase). Though stability is obtained with such orthoses, gait patterns are unnatural and non-cosmetic. Moreover, there is a lack of information about patient's performance with orthosis, specially during activities of daily living (ADL). The GAIT project (EU contract IST-2001-37751) aims to provide an integrated approach to active functional compensation and biomechanical evaluation of lower limb joints disorders. To achieve this goal, the project develops an active KAFO provided with a measurement system (sensors), actuators and an intelligent control system to regulate joints functions during walking and other common daily activities. The system is also conceived as a biomechanical monitoring tool, for both laboratory and daily use, capable of storing data and communicating wirelessly with a software platform for medical analysis.

Objectives: A set of requirements has been obtained at the first stage of the project, considering the actors involved (patients, rehabilitation physicians, orthotists, physical therapists and health insurance organisations). Aiming at a population of polyo myelitis and cerebral palsy young patients with an active lifestyle, the Gait project approach has two main applications: a) the improvement of the functionality of the orthosis by means of compensation strategies during walking and ADL such as sitting, standing up, negotiating stairs and slopes; and b) the monitoring of biomechanical (kinematics and kinetics) and comfort data of interest for the patient, physician, orthotist or physical therapist during daily use and also at laboratory.

System Concept: In order to realize these objectives, the Gait system is composed by a wearable set of sensors, actuators at knee and ankle joints, a control and monitoring ambulatory unit, all integrated in a custom designed knee-ankle-foot orthosis. A base unit allows the wireless communication of the portable units, through a Bluetooth® link, with a PC software platform conceived for on-line and off-line evaluation of data. Sensors adapted to the mechanical frame of the orthosis, collect kinematics, such as angles and angular velocities at lower leg joints and segments; kinetics, such as forces at the orthosis rods and fixation parts (to extract pressure information and moments around joints) and also foot contact information. Thus, the Gait approach features two main functionalities:

Active Functional Compensation: Control strategies are applied during level walking in order to achieve an adaptation of the lower leg joints ranges of motion and moments, through compensation by means of an actuator system. The actuators are designed according to linear elastic behaviours identified at specific phases during normal walking at the ankle and knee joints, and functional compensation is applied with timing

information of gait events as a control input. During the stance phase, the system aims to maintain the stability and avoid risk of falling, and during the swing phase, to allow knee flexion and avoid foot drag. Control strategies are also applied to allow a smooth and safe operation with automatic detection of transitions between activities (stable standing – sitting - negotiating stairs - negotiating slopes) looking forward to minimise the required patient intervention. Based on biomechanical data collected by the sensor set, real time algorithms under a state machine structure, are applied to detect gait phases and critical transitions for safety. Custom calibration of control parameters for individual cases from the software platform is performed through the wireless Bluetooth® link, allowing a better adaptation of the orthosis to the patient.

Monitoring and diagnosis: Biomechanical data and comfort signals are monitored wirelessly in a real time mode to the Software Platform and presented under different scenarios for each type of user (i.e. dynamic comfort parameters for a proper fitting of the orthosis). The control unit samples sensors signals at 60 Hz and stores it in a external memory for further analysis of data logs. This data logging during ADL is used for off-line analysis and discrimination of activities, rate of use as well as biomechanical and research data with algorithms developed at the Software Platform.

Hence, the GAIT project introduces a new generation of intelligent orthotic devices with improved functionalities and added capabilities aiming to increase the degree of acceptance of the user and the ease of prescription, fitting, maintenance and diagnosis procedures.