Chapter 3.11

Wearable Kinesthetic System for Joint Knee Flexion–Extension Monitoring in Gait Analysis

Mario Tesconi
University of Pisa, Italy

Enzo Pasquale Scilingo
University of Pisa, Italy

Pierluigi Barba
University of Pisa, Italy

Danilo De Rossi
University of Pisa, Italy

INTRODUCTION

Posture and motion of body segments are the result of a mutual interaction of several physiological systems such as nervous, muscle-skeletal, and sensorial. Patients who suffer from neuromuscular diseases have great difficulties in moving and walking, therefore motion or gait analysis are widely considered matter of investigation by the clinicians for diagnostic purposes. By means of specific *performance tests*, it could be possible to identify the severity of a neuromuscular pathology and outline possible rehabilitation planes. *The main challenge is to quantify a motion anomaly, rather than to identify it during the test.* At first, visual inspection of a video showing motion or walking activity is the simplest mode of examining movement ability in the clinical environment. It allows us to collect qualitative and bidimensional data, but it does not provide neither quantitative information about motion performance modalities (for instance about dynamics and muscle activity),

nor about its changes. Moreover, the interpretation of recorded motion pattern is demanded to medical personnel who make a diagnosis on the basis of subjective experience and expertise. A considerable improvement in this analysis is given by a technical contribution to quantitatively analyse body posture and gesture. Advanced technologies allow us to investigate on anatomic segments from biomechanics and kinematics point of view, providing a wide set of quantitative variables to be used in multi-factorial motion analysis. A personal computer enables a real-time 3D reconstruction of motion and digitalizes data for storage and off-line elaboration. For this reason, the clinicians have a detailed description of the patient status and they can choose a specific rehabilitation path and verify the subject progress.

In this context, the Gait Analysis has grown up and currently provided a rich library about walking ability.

In a typical Motion Analysis Lab (MAL), multiple devices work together during walking performance, focusing on different motion aspects, such as kinematics, dynamics, and muscular activity.

The core of the equipment used in the MAL is a stereophotogrammetric system that measures 3D coordinates of reflecting markers placed on specific anatomic "repere" on the body (Capozzo, Della Croce, Leardini, & Chiari, 2005). This instrumentation permits to compute angles, velocities, and accelerations.

The MAL is also equipped with force platforms, which reveal force profiles exchanged with ground on landing.

The electromyographic unit is deputed to measure muscle contraction activity by using surface electrodes. Pressure distributions can be obtained by means of baropodometric platforms, made up of a matrix of appropriately shaped sensors. A unique software interface helps the operator to simply manage data from the complex equipment.

BACKGROUND

Although its remarkable advantages, the Quantitative Gait Analysis require large spaces, appropriate environments, and cumbersome and expensive equipment that limit the use to restricted applications.

Moreover, the stereophotogrammetric system requires a pretest calibration and complex procedure which consists in the placement of reflecting markers on the subject body.

Electromyography may be obtrusive if needle electrodes are used to investigate deeper muscles or single motor unit activity. Because of this, although it is a widely accepted methodology, Gait Analysis is still quite difficult to be used in clinical contexts.

For these motivations, in the last few years technological research accepted the challenge of transferring any support and high level information close to the patient, better on the patient himself, by creating a *user friendly* patient-device interface. This means that health services can be brought out of their classic places with a remarkable improvement in health service and in health care based on prevention. Patient can be monitorized for longer time, ensuring the same high service quality at lower costs. A profitable combination of expertise and know how from electronic engineering, materials science and textile industry led to develop effective *Wearable Health Care Systems* (or simply *Wearable Systems*) (Lymberis & De Rossi, 2004). These latter ones had electronics integrated on traditional clothes, like on a breadboard. In order to allow subjects to freely move without constraints, improvements in materials manufacture, microelectronics, and nanotechnologies allowed us to develop a new generation of wearable sensing systems characterized by multifunctional fabrics (referred to as *e-textiles* or *smart textiles*), where electronic components are made up of polymeric materials, weaved or impressed on the fabric itself, without losing their original mechanical and electrical properties.

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