Chapter 73
Modular Acquiring System for Lower Limb Rehabilitation Machines

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The present paper refers to a research work aiming at implementing a modular acquiring system to be exploited in machines designed for lower limb muscles active rehabilitation. Mechatronic devices, as explained in [1] and [2], have given a relevant contribution to this field during last years, offering intensive treatments allowing individuals to restore as much as possible their motion capabilities, damaged by an injury, a disease or a lesion. But many machines do not have the possibility to obtain information about patient's biomechanical parameters during an active rehabilitation exercise. Starting from this concept, sensors, whether introduced into such devices, make accurate measurements and provide real-time data, which could be useful performance indicators, helping the physician to evaluate subject's condition and therapy efficiency, [1]. This work is articulated as follows: after having described the system, performed experimental analysis will be illustrated, and obtained results will be provided.

73.1 System Description

The acquiring system allows to get data about different parameters related to several magnitudes: (I) displacement carried out by moving mechanical structures, a sliding cart for instance, through a linear position transducer; (II) patient's Biceps femoris activity, thanks to an electromyographic analysis (EMG), by using three superficial electrodes attached to the thigh; (III) hip and knee flexion angles, with two accelerometers applied to leg and thigh, and (IV) machine resistant force, through a load cell. Sensors make the necessary measurements, while their analog outputs are received and converted by an acquiring board connected, through a USB port, to a PC, which executes an interface program, realized using LabVIEW software;

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such program elaborates the values coming from the board, to obtain the above mentioned information. When acquisition stops, all data are saved, in such a way they can be utilized whenever physician needs, for example to compare them with the ones resulting from previous therapy sessions. Sensors can be connected to the acquiring board in different ways, according to the desired analysis; this gives a great degree of flexibility and modularity to the system, allowing it to be utilized for a wide variety of applications. Its block scheme is represented in Fig. 73.1.

73.2 Experimental Analysis

Different analyses were performed, exploiting the acquiring system capability of collecting several types of data, according to rehabilitation purposes. Through the first one biomechanical parameters (i.e. angles and EMG signal) corresponding to the exercises proposed by two machines, called “a” and “b” for simplicity, involving the same muscular group, were compared. For both cases, electrodes were placed in the middle of subject’s thigh (to study Biceps femoris contraction), in correspondence of Pes anserinus and on tibial condyle, while accelerometers were attached to thigh and leg through two elastic bandages. Then, subject performed both exercises (firstly on a machine, then on the other one) flexing and extending his knees many times, while LabVIEW program was registering all the useful values.

Second analysis aimed at getting objective data about resistant force provided by device “a”, under different conditions (set by fixing a determined number of rubber bands), to obtain the one required to make properly the therapy exercise. One of load cell extremities was fixed, through a rope, to machine handle. Subject was standing and holding the other extremity with his hand. While LabVIEW program was running on the PC, he exerted a pulling action on that sensor to move the cart towards himself, until its limit, keeping the rod horizontal, as much as possible, with a velocity similar to the one employed during an ordinary exercise. He has maintained such position for a few seconds (typically between 15 and 25 s). Then, acquisition was stopped and subject released the cart. Many trials were performed, on different days and by more people, with increasing loads. In both cases, data were saved at the end of the acquisition and were elaborated using Microsoft Excel and MATLAB software.

73.3 Experimental Results

Figure. 73.2 shows the results obtained from the first analysis, i.e. flexion angles and EMG signal graphs related to the movements corresponding to the exercises performed with both rehabilitation devices.

It is evident that the one with machine “b” implies only knee flexion (while hip movement is negligible), whereas the one with device “a” assures hip and knee

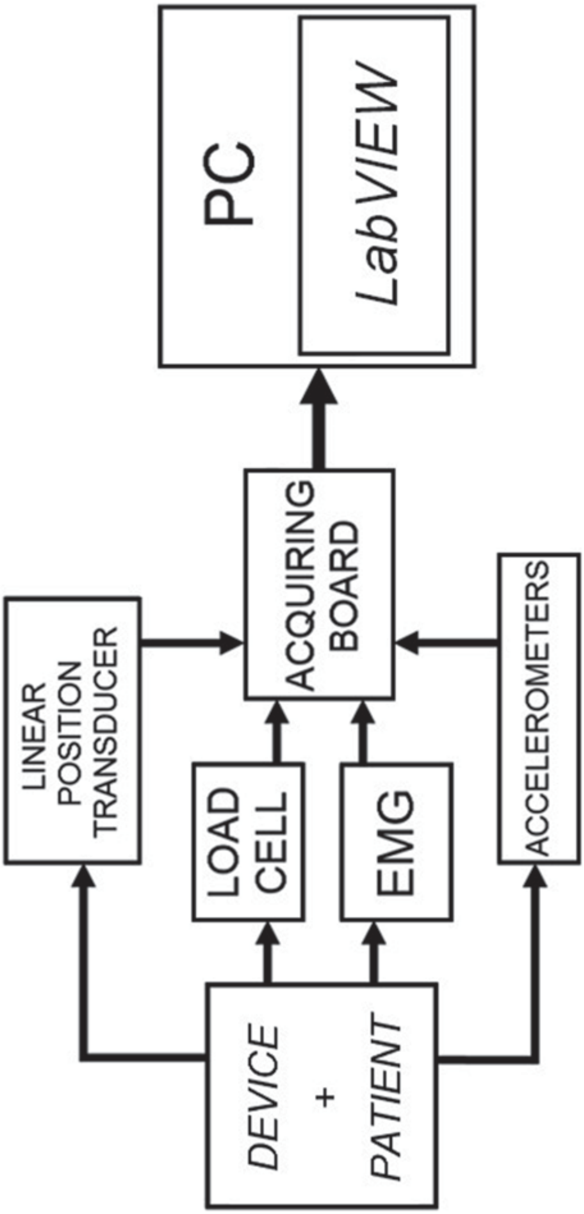

Fig. 73.1 Acquiring system block scheme

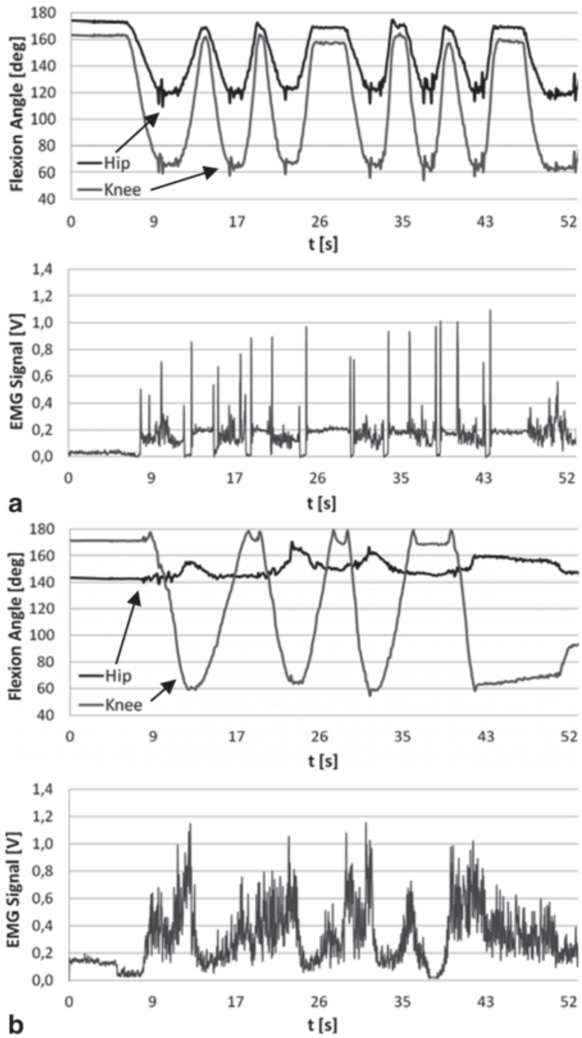

Fig. 73.2 Graphs of biomechanical parameters (hip and knee flexion angles and EMG signal) referring to the exercises performed with: **a** machine "a", **b** machine "b"

synchronous flexion, according to patient's natural kinetic chain; furthermore, EMG exam on Biceps femoris helps to understand that movement with machine "b" starts to activate this muscle at the beginning of knee flexion (concentric phase), with a peak when knee angle reaches its minimum value, whereas device "a" implies a more controlled and gradual muscle activation, mostly during extension (eccentric phase, as happens in running); in fact related signal is less noisy and the greatest part of its peaks is in correspondence of the beginning of such phase, or when

Table 73.1 Force intervals corresponding to different conditions

Rubber bands	Maximum force (kg)	Position maintaining force (kg)
1	12.0 ± 0.9	6.0 ± 0.7
2	16.5 ± 1.4	12.4 ± 1.0
3	23.8 ± 2.0	17.3 ± 0.6
4	28.2 ± 1.5	22.8 ± 0.5
5	34.5 ± 2.2	28.1 ± 1.1
6	41.4 ± 1.1	33.6 ± 1.0

knee angle reaches its maximum. A few peaks, less intense, are present also at the beginning of concentric phases; this can be due to the use of superficial electrodes, which could have involved fibers from other muscles.

Second analysis allowed obtaining proper force intervals for different numbers of rubber bands. They are listed in Table 73.1. Thus an indication about the force to provide in order to perform a suitable exercise is achieved. Maximum force refers to total effort for cart moving until its limit, whereas Position maintaining force is related to the one for keeping such position.

73.4 Conclusions

This article describes an acquiring system which has been implemented in two lower limb active rehabilitation devices (its modularity and most of all its capability of gathering different data for specific aims has allowed its efficient adaptation to these machines), to monitor biomechanical parameters during treatment, helping the physician to evaluate patient's condition and therapy effects. Furthermore, it has proved to be very useful to show the differences between the exercises proposed by such instruments and to obtain reasonable force intervals related to a proper execution of the exercise with machine "a".

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