Assistive Smart Sensing Devices for Gait Rehabilitation Monitoring

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Abstract. Smart sensing devices are nowadays part of the ambient assisted living architectures and may be adapted and personalized for gait rehabilitation assessment. Aiming an objective evaluation of patient progress during the physiotherapy sessions, the design and implementation of a set of sensing devices were carried out. Thus, it was considered a wearable solution materialized by a smart inertial measurement unit (IMU) and/or a set of walking aid objects characterized by embedded unobtrusive sensing units based on microwave Doppler radars. The data delivered by the smart sensing units designed for gait rehabilitation purpose are wireless transmitted to an advanced processing server that provides synthetic information to the physiotherapist that use a mobile device to access the available services. Elements of IMU sensor network and smart rollator design and implementation for gait assessment, as well as sensor signals digital processing, are included in the chapter. AQ1

Keywords: Microwave doppler radar · Inertial measurement system · Gait monitoring · Time frequency analysis AQ2

1 Introduction

In gait-related clinical practice, the knowledge of the accelerations and velocities associated with the gait performed by the monitored patient are very important to diagnose gait patterns and to evaluate therapeutic interventions [1]. The analysis of the human body movement is commonly done in so-called 'gaits laboratories'. In these laboratories, body movement is measured by a camera system using optical markers [2], the ground reaction force (GRF) using a force plate fixed in the floor [3], and the muscle activity using EMG [4]. From the body movements and ground reaction forces, joint moments and powers can be estimated by applying inverse dynamics methods [5] providing estimate of the rehabilitation progress. Considering the lack of application of this kind of systems for real environments where physiotherapist and doctors assist the people under physiotherapy, an important challenge is to design and implement, reliable, easy to use, and low cost systems for gait measurement and analysis that can be used by physiotherapist during normal physiotherapy sessions or can be easily included as part of remote physiotherapy services [6]. At the same time, the developed systems

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for gait measurement and analysis might be prepared for the particular case of patients that are using walking aids during motor rehabilitation.

Frequent solutions used for objective evaluation of rehabilitation processes are based on the use of inertial sensors attached to the human body [7, 8]. A set of wearable solutions developed by Postolache et al., characterized by Bluetooth connectivity as part of a smart system was used for motor and cardiac activity monitoring [9]. Interoperability and modularity were considered as important requirements for the latest developments in the smart sensors for vital signs and motor activity monitoring that conducted to a flexible multiprocessor plug-and-play architecture characterized also by multiple wireless connectivity capabilities [10]. The use of smart sensing solutions imposes the necessity to fix the sensing module in an appropriate way, which requires preparation from the physiotherapist to perform that task. In the case of remote physiotherapy, in addition to discomfort associated with long period of use, it could require special knowledge and motor ability from the user part, which limits the use of this type of systems. Taking into account that many patients use walkers or rollators during the physiotherapy, we designed unobtrusive solutions for gait rehabilitation monitoring by embedding sensors in this kind of equipment to extract the patient's motion information. Several authors reported the developing of walkers or rollators with capabilities to sense the motion and forces that should characterize the users gait during the physiotherapy sessions and provide this information to the physiotherapist in appropriate way [11–14].

In this chapter are presented as set of solutions for physical rehabilitation monitoring that include MEMS and microwave Doppler radars associated with human body as accessories or embedded in walking aids expressed by walkers and rollators.

The chapter is organized as follows: we start by presenting the IMU (inertial measurement unit) body area network, special attention being granted to the end-nodes that include 3D accelerometers and gyroscopes. Then, use of microwave Doppler radar to provide motion sensing capabilities for a rollator is introduced. In Sects. 4 and 5 the software aspects related with the system operation and with digital signal processing for gait analysis are detailed and some illustrative results presented. A short conclusion ends the chapter.

2 IMU – Wireless Network

The latest developments in micro-electro-mechanical systems (MEMS) makes possible to integrate multiple sensors, including gyroscopes, accelerometers and magnetometers, in a compact inertial sensor module, which may also include a digital processing unit for data fusion. This type of implementation is known as inertial measurement unit (IMU) and provides all the information needed for the detection of human movement [15].

The IMU applications were developed in the field of pedestrian dead reckoning (PDR). Step detection, walking speed and step length measurement are proper to the PDR and, at the same time, are considered important elements to evaluate the gait during rehabilitation sessions. To measure these quantities we propose here a motion wireless node based on an IMU board developed in our laboratory (Qk motion) [16].

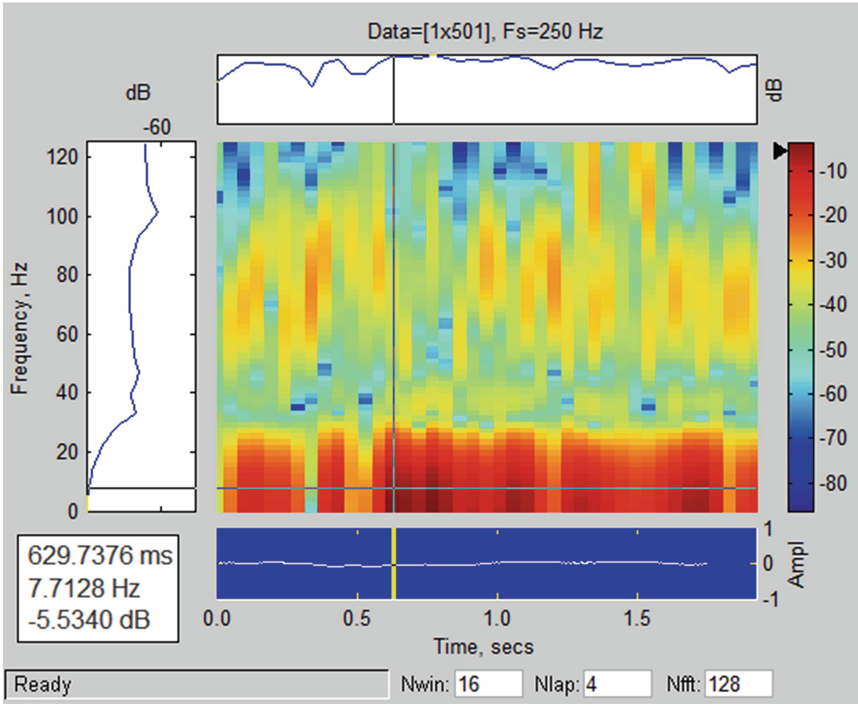

Fig. 7. The evolution STFT spectrogram associated with VI1_n normalized voltage for a time window of 2 s.

6 Conclusion

This chapter addresses the thematic of smart sensing devices for gait rehabilitation monitoring. An inertial measurement unit sensor network and 24 GHz FMCW Doppler radar arrays are introduced and their integration in a smart rollator is detailed. The system is able of capturing kinematic walking parameters and the gait information during physiotherapy sessions, permitting an objective and unobtrusive evaluation of gait rehabilitation progress. A particular attention was dedicated to several details related with the implementation and development of software modules to process measurement data and to evaluate gait parameters.

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