Ethernet Motion-Sensor Based Alarm System for Epilepsy Monitoring

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ABSTRACT

In several biomedical domains, it would be interesting to monitor subjects over night time using wearable motion sensors and trigger an alarm if a specific movement has been detected by processing the accelerometer readings. In this paper, the authors describe an innovative architecture for such an alarm system in the context of epilepsy monitoring. The main ingredients of the proposed system are wireless motion sensors, a radio-frequency transceiver linked to an Ethernet gateway and an acquisition server that incorporates real-time detection method. This motion analysis system is further integrated in the dataflow of an existing medicalized alarm system and an event is sent to healthcare professionals every time a seizure is detected by the expert system. The EPIMOUV system has been evaluated, during a 6-month period, in a specialized institution with epilepsy pharmaco-resistant residents.

Keywords: Accelerometer, Alarm Detection System, Epilepsy, Ethernet, Motion Analysis System, Motion Sensor

1. INTRODUCTION

Nowadays, body-mounted inertial sensors are increasingly used in biomedical applications (Luinge et al., 2007). Their main advantages are miniaturization, autonomy, low intrusiveness and unrestricted application range. In environment-controlled laboratory setups, they have shown to be reliable for upper-limb (kinematic analysis) and lower-limb (gait analysis),

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and they do fare well against optical tracking devices. In ecological situations, body-mounted sensors have also been used either for continuous physical activity monitoring or for rare-event detection (e.g., fall detection). Depending on the application at hand, motion data are either recorded on data-logger for subsequent offline analysis or has to be processed in real-time on dedicated robust architectures. In the latter case, data is usually transmitted to a PC or a PDA to trigger an alarm to the exterior world. The transmission would be preferably wireless or wired.

In specialized institutions, there is definitely a need to monitor the patient in his room and to collect data remotely at a network scale either for offline analysis, e.g., sleep monitoring or online movement detection. This (new) way of handling data could also be integrated very conveniently in hospital dataflow. The main objective of this paper is the description of such a remote motion-capture acquisition system coupled with a dedicated medical alarm system, in the context of epilepsy.

Epilepsy is characterized by paroxystic and sudden seizures and varies among humans in terms of manifestations, severity, and frequency of occurrence. It is one of the major neurological diseases that affect 1% of the population worldwide. The EPIMOUV project aims at providing a place to live and autonomy for drug-resistant epileptic young adults while attempting to provide them a high level of security. In this framework, subjects will be monitored during night using body-worn wireless motion sensors and an alarm will be triggered if an on-going nocturnal seizure is detected by processing the accelerometer readings from torso and wrist sensors. Indeed motor manifestations are frequent during seizures and their topographical meanings vary according to the different types while being reproducible for a given subject. In each monitored room, wireless accelerometers will transmit data to a radio-frequency (RF) transceiver linked to an Ethernet gateway. The main application is driven from a remote PC for configuration and data acquisition and it is interfaced with a medicalized alarm system. The whole architecture will be described in detail in this paper. The second objective of the paper is to present preliminary evaluation results that have been obtained during a 6-month period.

This article is organized as follows: First, we present the main components of the Ethernet-based motion capture system and its application to the specific case of nocturnal seizure alarm system. Then we discuss the evaluation results of the proposed approach. The main conclusions of this work are drawn in the end.

2. METHODS

2.1. Ethernet-Based Motion Capture System

The proposed Ethernet-based solution is build upon watch-sized MotionPod® technology from Movea. The different building blocks of the retained solution are described next with the wireless motion sensor and then the Ethernet RF receiver.

MotionPod™ is a patented solution of motion sensing technology for accurate human body orientation or motion measurement. This is done by using miniaturized high-tech motion sensing MEMS containing 3-axis accelerometers (3a) and 3-axis magnetometers (3m) incorporated into a silicone rigid casing. One of the major advantages of this micro-system is that it is an easy-to-use, multi-node wireless solution, providing a wide spectrum of information on movement. Table 1 gives some figures about the characteristics of the MotionPod™ technology.

The 3a3m sensors (up to 16) do communicate with an RF-receiver that redirects the motion data towards a PC via a USB link. Each MotionPod is time-synchronized by the controller and a TDMA protocol is used for data transmission. The MotionPod USB Controller is also the docking element for battery charging. The different elements are illustrated in Figure 1.

Sensor frame and mounting frame calibration procedures are applied according to Bonnet et al. (2009). For each modality, these procedures allow respectively the determination
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