Chapter 20

A Full-Body Wireless Wearable UWB-Based Human Motion Capture and Gait Analysis System

Heba Shaban
Arab Academy for Science, Technology & Maritime Transport, Egypt

Mohamad Abou El-Nasr
Arab Academy for Science, Technology & Maritime Transport, Egypt

R. Michael Buehrer
Virginia Polytechnic Institute and State University, USA

ABSTRACT

Gait analysis is the systematic study of human walking. Clinical gait analysis, also termed as quantitative gait analysis, provides a detailed clinical introduction to understanding and treating walking disorders. Modern gait analysis is facilitated through the use of specialized equipment. Currently, accurate gait analysis requires dedicated laboratories with complex settings and highly skilled operators. Wearable locomotion tracking systems are available, but they are not sufficiently accurate for clinical gait analysis. On the other hand, wireless healthcare is evolving. Ultra wideband (UWB) is one technology that has the potential for accurate ranging and positioning in dense, multi-path environments. In particular, impulse radio UWB (IR-UWB) is suitable for low-power implementation, which makes it an attractive candidate for wearable and battery-powered health-monitoring systems. The goal of this chapter is to propose and investigate an accurate, full-body, wireless, wearable human locomotion tracking system using UWB radios, with specific application to clinical gait analysis.

DOI: 10.4018/978-1-61350-123-8.ch020

INTRODUCTION

Observational gait analysis, the standard method of evaluating gait, refers to the visual assessment of a patient's gait. Gait analysis by observer assessment does not use any specialized equipment, and is simply used to observe abnormalities in gait. Clinical gait analysis, also termed as quantitative gait analysis, provides a detailed clinical introduction to understanding and treating walking disorders (Gross, Fetto et al. 2002; Menz, Latt et al. 2004). The identification of gait disorders is commonly assessed by the measurement of the spatial and temporal parameters of gait[1]. However, it is worth noting that the techniques and technologies that work well for measuring normal gait often fail when applied to abnormal gait (Kiss, Kocsis et al. 2004; Cappozzo, Della Croce et al. 2005). Moreover, the criteria valid for clinical research are not necessarily the same as those valid for clinical testing (MacWilliams and and D'Astous 2002; Menz, Latt et al. 2004). Accurate measuring systems, optical tracking systems, are available, but they require that the test subject move inside a dedicated laboratory with multiple charge-coupled device (CCD) cameras and complex settings (Gross, Fetto et al. 2002; Di Renzo, Buehrer et al. 2007). Subtle abnormalities are not evident when examined indoors, as when walking is performed in a laboratory with the patients concentrating on what they are doing, since this does not necessarily represent their normal walking (Gross, Fetto et al. 2002). On the other hand, body-fixed-sensors do not require such complex settings or highly skilled operators. Yet, these systems also have their limitations. A possible solution for overcoming these limitations is to use multiple sensors, or what is known as sensor-fusion (Cappozzo, Della Croce et al. 2005; Corrales, Candelas et al. 2008). However, the overall power consumption and system cost remain as two limiting factors, where sensory systems are commonly expensive.

The work of this chapter is motivated by the properties of ultra wideband (UWB) technology as a promising candidate for real-time human locomotion tracking with specific application to clinical gait analysis. In this chapter, we introduce and investigate a full-body wireless wearable human locomotion tracking and gait analysis system using UWB radios that is capable of providing high ranging and localization accuracies. In particular, we design the primary components of the proposed system with specific application to clinical gait analysis.

The key design challenges that will be addressed in this chapter are organized as follows. Initially, the target ranging accuracy, required signal-to-noise-ratio (SNR), and target sampling rate will be specified. Based on these requirements, the calculation of the achievable SNR is necessary for determining the feasibility of the system under investigation. Then, the possible receiver structures will be exploited. Furthermore, the choice of the appropriate receiver structure as well as the selection of the corresponding design parameters that enable for the achievement of the target ranging accuracy will be presented. Moreover, the arrangement of transceivers (nodes), number of nodes and their locations are important factors that will studied, since these factors directly affect the motion capture data. Then, the determination of the relative positions of nodes during movement based on the acquired ranging data and dynamics of human movement is a challenging task that will be tackled, where all-nodes are mobile. Finally, sensor-fusion, system performance, and battery lifetime will be studied.

The organization of this chapter is as follows. First, we give a brief background on gait analysis and highlight the advantage of the application of UWB to healthcare applications including the available receiver structures, power consumption requirements of wireless body area networks (WBANs), and time-of –arrival (TOA) lower bounds. Then, we give an overview of our proposed system followed by the link budget design parameters. The ranging stage is then presented with the corresponding receiver structure and

Related Content