A Wireless Human Motion Capturing System for Home Rehabilitation

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***Abstract*—Following the trend of miniature intelligent sensing, wearing small, integrated wireless sensor nodes, such as one with accelerometers and compasses, to capture human body motions may have many applications in medical care and computer animation. In this paper, we demonstrate the use of intelligent sensors to capture human motions for home rehabilitation. We design a game to help a patient to conduct his/her rehabilitation program. For each exercise, the patient is instructed to wear sensors on specified movable body parts. The system will then estimate the quality of the movements and give scores as if it is advised by a therapist. In this way, patients will no longer feel painful and boring as that in traditional rehabilitation, which is typically done in hospitals.**

I. Introduction

The advance of Micro Electro Mechanical Systems (MEMS) and wireless technology has boosted wireless sensor networks (WSN), where wireless sensors are deployed to monitor the environment. Following this trend, wearing small, integrated wireless sensor nodes, such as one with accelerometers and compasses, to capture human body motions may have many applications in medical care [1] and computer animation [2]. In contrast to traditional motion capturing systems, which use optical devices, such as a set of cameras, using wearable sensors is much cheaper and immune to the line-of-sight problems in optical-based systems.

The wireless body-area network (WBAN) technology also brings new light to medical care and tele-rehabilitation. As the aging population has increased significantly in the past decades, long-term healthcare has posed an increasing load for therapists and become an important challenge in the society. Traditionally, physical rehabilitation programs are instructed and monitored by therapists in the hospital, and thus consume severe medical resources. Furthermore, since the rehabilitation process is typically lengthy and boring, many patients may be reluctant to take it, thus further reducing its effectiveness.

In this paper, we will demonstrate a system that uses intelligent sensors to capture human motion for home rehabilitation. The system consists of three parts: a wireless sensing platform, a motion analysis module, and a game interface. A patient needs to wear sensors on specified body parts. The motion analysis module evaluates the quality of a patient's movements and gives feedback through the game interface.

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II. System Description

Fig. 1 shows our system architecture. Here we consider a set of Pilates exercises for low back pain relief (refer to Fig. 2) as suggested by the therapists in Wan-Fang Hospital, Taipei. For each exercise, the game interface will instruct the patient to wear sensors at appropriate body parts.

Wireless Sensing Platform: We have tested two platforms: Octopus II and ECO systems (refer to Fig. 3). Octopus II is modified from the Tmote Sky system [3] and runs TinyOS, while ECO [4] is quite tiny and is extremely resource-limited. Both platforms use the TDCM3 electrical compass. Octopus II uses the FreeScale MMA7260QT accelerometer and ECO uses the Hitachi-Metal H34C accelerometer. These tri-axial accelerometers can capture the gravity in x, y, z-axes. Note that a compass is needed since the rotation angle about the gravity cannot be inferred from the accelerometer along. Octopus II uses a TDMA protocol provided by TinyOS to increase data rate. On the otherhand, ECO adopts a simple polling protocol. On the sink side, the acceleromter and compass readings from each node are further combined into orientation matrices in the world coordinate.

Motion Analysis Module: This module takes the accelerometer readings and the orientation matrices as input to reconstruct the patient's motions and gives scores. One major parameter of motions is the joint angle information ($\alpha_1, \ldots, \alpha_4$ in Fig. 1). Another is the angle between each sensor node and the gravity direction (β in Fig. 1). Our scoring mechanism analyzes these parameters to judge if the patient's performance is acceptable or not. For instance, the patient is considered to perform exercise (a) in Fig. 2 well if (1) the joint angle between two legs is around $45°$, and (2) the movement of his pelvis is within a small range. Item (1) is implemented by restricting the joint angle within $45° \pm 10°$, and item (2) by restricting β, the angle between the frontal plane and the gravity direction, within a small range.

Game Interface: This layer interacts with the user and stores the results of each exercise. The game has multiple levels, each as one Pilates exercise. The game will create some events, and the patient should react by performing the

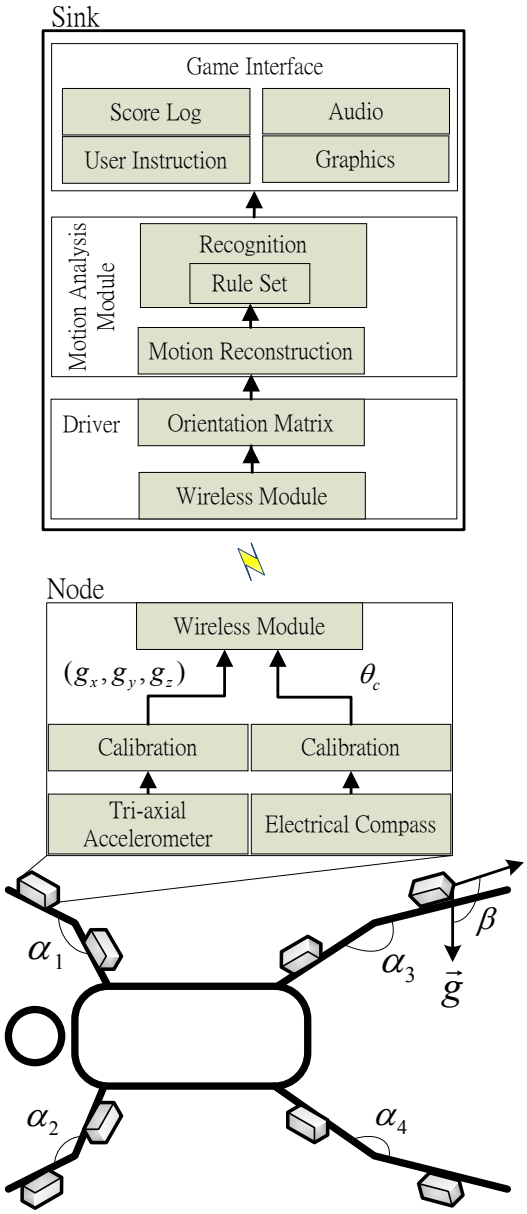


Fig. 1. System architecture.

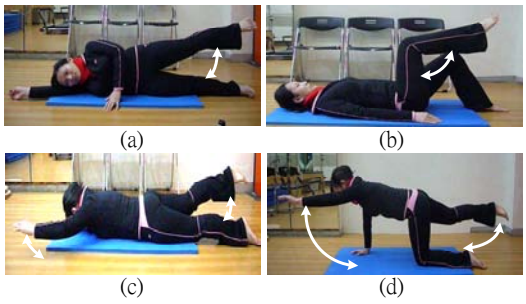
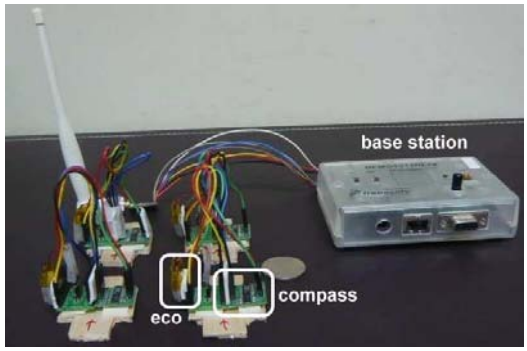
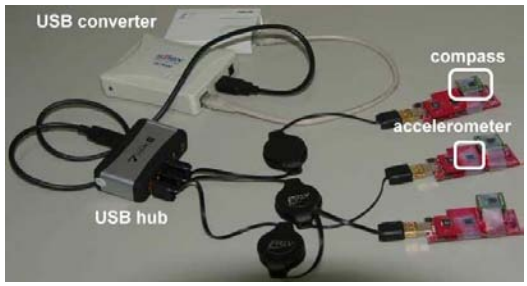


Fig. 2. Pilates exercises for low back pain relief.

specified Pilates exercise. The game interface queries the motion analysis module to check if the patient's performance



(a) ECO system



(b) OctopusII system

Fig. 3. Our wireless sensing platforms.

is acceptable, and if so, some rewards are given. The patient should get enough rewards to pass a level. Most of the hints are shown on the screen, but if the patient cannot watch the screen in some Pilates exercises, audio hints will be given instead.

III. Demonstration

We will demonstrate exercises (a) and (b) using Octopus II and ECO, respectively. In exercise (a), the game is to open a treasure box. The player should raise his leg to about $45°$ to open the lid and collect at least 5 treasures to pass this level. In exercise (b), the player should keep his knee joint angle to about $90°$ and raise two legs up simultaneously.

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