Gaming for Upper Extremities Rehabilitation

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ABSTRACT

This paper presents a hand motion capture system. Its application is a wearable controller for an upper extremities rehabilitation game. The system consists of a wearable data glove platform (SmartGlove, a customized finger pressure, bending, and 9DOM motion extraction platform) and a 3D camera vision device (Kinect [1], vision based game controller supplied by Microsoft) to extract detailed upper extremities parameters as gaming inputs. The testing application is a jewel thief game [2] implemented with C# and Unity, which requires the tester, such as a stroked patient with upper extremities disabilities to perform a series of predefined upper extremities movements to accomplish the assigned jewel grasping tasks. The parameters and timing could recorded during the gaming process for further medical analysis. This system is targeted on lowering the cost of rehabilitating impaired limbs, providing remote patient monitoring, and acting as a natural interface for gaming systems. In addition, the extracted parameters can be exploited to reconstruct of an accurate model of the patient's limbs and body. Therefore, the proposed system can provide remote medical staffs a wide variety of information to aid a patient's rehabilitation, including, but not limited to aiding in progress evaluations and direct rehabilitative exercises and entertainment.

Categories and Subject Descriptors

J.3 [**LIFE AND MEDICAL SCIENCE**]: :Health and Medical Information Systems

General Terms

Design, Economics, Reliability, Experimentation

Keywords

Upper extremities rehabilitation, exercise, gaming, health, data glove, calibration, fusion, 3D camera, Kinect, IMU

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1. INTRODUCTION

Upper extremities disabilities can come from various possible sources, such as military injuries, sports injuries, stroke, etc. An annual incidences survey about the cost of the stroke reveals that approximate 4.6 million dollars are spent annually for stoke in 2003. By 2030, it will be a major cause of disability and loss of quality of life among adults. Approximately 60% of stroke patients experience long-lasting activity limited arm and hand motor dysfunctions, mood disorders, and chronic pain [3]. The limitations in current therapy system are that the therapy process requires constantly manual monitoring and the equipments are far from affordable [4]. Even though low cost wearable MEMS technology is introduced into the upper extremities rehabilitation process [5], a major restriction of these existing wearable sensor systems is the inability to provide accurate hand positional data, especially when the wearable sensor system relies on an inertial measurement unit (IMU) to provide that data [6]. The proposed system utilizes an additional vision system to provide accurate positional data and to calibrate the wearable sensor platform constantly. Likewise, traditional low-cost vision systems, such as the ones used for motion capture do not provide sufficient image resolution to track fine-grained finger motor functions [7]. The proposed system utilizes a SmartGlove as a hand parameters extraction sensor, which is worn directly on hand and extracts hand parameters to provide finer finger motion information which cannot be identified by most of common vision systems. In addition, our solution provides an economic platform designed for physical upper extremities rehabilitation through an interactive object grasping game. Upper-extremities movements and fined-grain hand gestures are integrated and exploited as high-dimensional inputs to provide detailed descriptions of the user hand profile. Real-time data processing further facilitates rehabilitative efforts and enhances user comfortableness during the long-term rehabilitation process.

2. SYSTEM DESCRIPTIONS

Our proposed system is composed of three parts, including a wearable glove sensor platform, a vision device, and a jewel thief game for the upper extremities rehabilitation tests.

2.1 SmartGlove

In the sensor platform, we utilize a glove that has been fitted with pressure sensors with pressure sensitive ink technology [8] and bending sensors with resistive-based membrane potentiometers [9]. These sensors provide physical force readings at the fingers as well as the finger curl angles, while an IMU [9] provides motion and orientation data. To provide haptic feedbacks, a shaft-less vibratory motor is also mounted to provide haptic feedback to the user [9]. The sensor data are collected and quantified with low-power TI MSP430-RF2500 evaluation board [10], which contains 10 bits analog to digital converters and a Zigbee RF transmitter. And a corresponding receiver dongle is on the PC end. The sampling rate used for seamlessly gaming experience ranges from 10Hz to 100Hz, and the data transmission rate is limited by the available serial port transmission rate: 115200 bps. However, the data rate of the system is sufficiently fast to perform near-lossless motion tracking.

2.2 Vision System

The vision system is a kind of off-the-shelf consumer products, the Microsoft Kinect, originally used by Microsoft as a controller for the Xbox 360 console. We chose to use Kinect because of the wealth of information available to hobbyists, as well as its hacker-friendly nature, and its affordable cost compared to more specialized vision hardware. Kinect provides 3D positional data about a person in its field of vision through use of a 3D scanner system based on infrared sensor. It has additional hardware such as RGB cameras and microphones, enabling it to record normal video streams as well. Kinect can utilize the microphones for 3D positioning purpose, though we do not make use of this application yet.

2.3 Jewel Thief Game

The jewel thief game initially is designed for arm rehabilitation purpose with a pure camera tracking system at USC ICT [11]. The training game is now extended to rehabilitate and monitor upper extremities disability, including arm, finger joint and a variety of hand/finger gestures with the introducing of the SmartGlove system and the proposed sensor integration system to calibrate and fuse both data streams retrieved by SmartGlove and Kinect vision system.

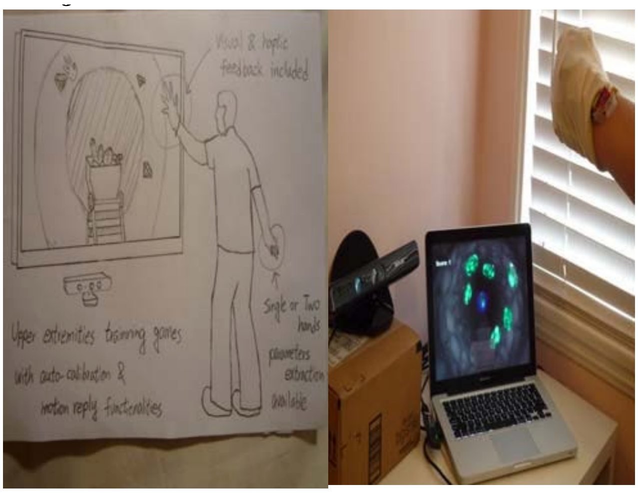

Figure 1: Sketch and Photo of the Jewel Thief Game

The game procedures are described as follows. The user is asked to wear the SmartGlove and turn on the glove power. Although the data glove can be calibrated ahead, it can also be online calibrated if the glove calibration mode is selected. The glove calibration process assures that the pressure sensor, bending sensor, and IMU are in the consistent states. When the Jewel Thief game is started, the user is required to create or load his/her profile and be tracked by the Kinect camera. After the camera tracking calibration, the user can see a silver foil on the screen which will move based on the hand movement and the tracking parameters is reserved as IMU offline tracking information. For now on, the user is ready to go through a series of rehabilitation training process.

The jewel thief game shows a set of shining jewels on the screen which are assigned by a physical therapist to guide the user which jewel to grasp. The user should follow the hints, approaching, grasping the jewel, and then putting it into the basket in the screen. Failing to grasp the jewel firmly may lose the jewel in the course of the jewel retrieving, so that the user needs to re-grasp it from where he/she lose it and repeat the same process to complete the training. Since the gaming time is recorded and the hand parameters are recorded, any inappropriate timing and gestures will be reported to the remote care-taker whenever a network is available. In addition, a vibration feedback signal is toggled when the user grasps or loses the jewel in the middle of the game. Through gaming, the user can follow the guidance of the physical therapists and finish their required rehabilitation training unconsciously. In addition, this low-cost, portable and wearable system makes the remote rehabilitation possible and affordable, which is the key to deal with the gradually increasing needs of the upper extremities rehabilitation in practice.

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