Chapter 36

Development of a Bilateral Assistance and Coordination Rehabilitation Training System

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ABSTRACT

Strokes can lead to lasting neurological impairments. Many researchers are studying this process and have made important discoveries. Researchers are starting to investigate the possibility of neurorehabilitation based on neuroplasticity. On the other hand, robot assisted systems have increasingly been used in rehabilitation. However, studies on bilateral assistance rehabilitation systems have seldom been reported. Industrial robot arms were proposed for rehabilitation in other studies, but the inertia and volume of the system was too large, and the stiffness was hard to change. In this research, the authors proposed a novel bilateral assistance rehabilitation approach to treatment of the upper limbs of stroke patients, and a bilateral coordination rehabilitation approach was also proposed. This system is based on virtual reality, and is composed of two haptic devices (PHANTOM Omni), an advanced inertial sensor (MTx), and a computer. The authors have built some force models, in which one hand can be used to assist the other. Bilateral coordination training can also be performed in rehabilitation. In this system, the virtual reality technique is adopted to provide a virtual force model for rehabilitation training of the upper limbs. Furthermore, it is easy to change the stiffness of the system through changing the parameters of the developed virtual force model. The advantages of high safety, compactness, and bilateral assistance and coordination training make the system suitable for home rehabilitation.

DOI: 10.4018/978-1-60960-559-9.ch036
INTRODUCTION

Stroke can result in neurological impairments. Approximately 700,000 people suffer a first or recurrent stroke each year, according to the American Heart Association [http://www.americanheart.org/statistics/stroke.htm]. Traditional therapy requires many therapists and increases the health care burden. To solve this problem, robot-mediated rehabilitation systems have been developed (R.F. Boian, M. Bouzit, G.C. Burdea & J.E. Deutsch, 2004).

In 1995, a rehabilitation system named MIT-MANUS was developed at the Massachusetts Institute of Technology, Cambridge (N. Hogan, H. I. Krebs, A. Sharon & J. Charnnarong, 1995; H. I. Krebs, B. T. Volpe, M. L. Aisen & N. Hogan, 2000). The device assisted planar pointing and drawing movements with an impedance controller. Unlike most industrial robots, MIT-MANUS was configured for safe, stable, and compliant operation in close physical contact with humans. This was achieved using impedance control, a key feature of the robot control system that modulates the way the robot reacts to mechanical perturbations from a patient or clinician and ensures gentle, compliant behavior. MIT-MANUS can move, guide, or perturb the movement of a subject’s or patient’s upper limb, and can record motions and mechanical quantities such as the position, velocity, and applied force. The profile of the system is shown in Figure 1. Several redundant safety features were incorporated into the system.

1. Software cut power to the robot if the error between the commanded and measured angles at the robot’s joints exceeded a critical value. This would occur if the robot had encountered an unexpectedly large resistance.
2. A commercially available pneumatic device cut power to the robot when the torque applied to the forearm exceeded a critical value (20 Nm). Straps limited the robot to a safe range of motion.
3. The experimenter always kept an emergency stop button nearby.

Another typical rehabilitation system, called the MIME assisted rehabilitation system is shown in Figure 2. Preliminary reports of the system were presented in 1999 at the 6th International Conference on Rehabilitation Robotics (ICORR ‘99), Stanford, CA. The initial version of MIME incorporated two commercial mobile arm supports modified to limit arm movement to the horizontal plane, and a 6-DOF robot arm (PUMA-260) that applied forces and torques to the paretic forearm through one of the arm supports. In the current MIME workstation, the robot is a Puma-560, the paretic limb mobile arm support is eliminated, and a 6-DOF-position digitizer is applied to the system. (R.M. Mahoney, H.F. Machiel Van der Loos, P.S. Lum & C.Burgar, 2003) Redundant hardware and software features assure subject safety while exercising in the MIME.

The ARM Guide (Kahn, L.E., Zygman, M.L, Rymer, W.Z. & Reinkensmeyer,D.J, 2006) is a singly-actuated, four-DOF robotic device that consists of a hand piece attached to an orientable linear track and actuated by a DC servo motor.
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