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TECHNICAL NOTE

Serious game and functional rehabilitation for the lower limbs

Jeux sérieux et rééducation fonctionnelle des membres inférieurs

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Summary
Introduction. — Conventional functional rehabilitation consists of a therapeutic consultation, a motor exercise assignment, and an execution task with or without assistance of the therapist. The objective of this technical note was to present a new real-time 3D serious game system concept for musculoskeletal rehabilitation of the lower limbs.
Materials and method. — A generic development workflow of real-time 3D serious game systems for functional rehabilitation of the lower limbs was proposed. A user-friendly system flowchart was also established for a better interaction between end-users and the game system.
Result and discussion. — Different system components like avatar modeling, subject registration, rehabilitation game and feedback visualization and control were detailed and their advantages and limitations were discussed.
Conclusions. — 3D serious game technologies open new perspectives for a large range of rehabilitation applications (at home or in clinic environment, sports training).

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Supervision en temps réel ;
Rééducation à la maison ;
Vision 3D par ordinateur

Résumé
Introduction. — La rééducation fonctionnelle consiste en une consultation thérapeutique, une affectation et une exécution des exercices de rééducation avec ou sans aide du kinésithérapeute. L'objectif de cette note technique est de présenter un nouveau système de jeux sérieux 3D pour la rééducation fonctionnelle des membres inférieurs.
Matériel et méthode. — Un processus de développement générique des systèmes de jeux sérieux 3D pour la rééducation fonctionnelle des membres inférieurs a été établi. Un processus d'interaction a été aussi proposé pour faciliter l'utilisation du système et les utilisateurs finaux.
Résultat et discussion. — Les composantes et modèles (la modélisation de l'avatar, le recalage du sujet, les jeux de rééducation fonctionnelle et l'interface home machine) du système sont présentés. Leur avantages et limites sont aussi discutés dans le contexte de rééducation fonctionnelle.
Conclusions. — Les technologies de jeux sérieux 3D ouvrent de nombreuses perspectives pour une large gamme d'applications de rééducation fonctionnelle (à la maison ou dans la routine clinique, ou l'entraînement sportif).

Introduction

Human movement is the most basic function of the human being. Physical disabilities [1,2], due to genetic or infectious conditions, traumatic events (e.g. transport or sports accidents) or aging, strongly affect the control and organization of human movement. Functional rehabilitation exercises have been commonly assigned for each involved patient by the medical staff [3]. One of the most important roles of functional rehabilitation is to recover or regain mechanical functions of the human body. Conventional functional rehabilitation consists of a therapeutic consultation, a motor exercise assignment, and an execution task with or without assistance of the therapist. This approach has showed some practical limitations. For example, the therapist guides and helps the patient during each exercise, so in such a way, the rehabilitation efficiency may depend on the therapist's experiences. Moreover, due to the repetitive and insistent nature of rehabilitation exercises, the mental state of the patient might be affected, and the performance of the patient might decrease. Thus, the efficiency of the rehabilitation program depends also on the patient's motivation. One of the potential solutions to improve the rehabilitation process is to provide validated objective indicators to monitor the performance of the rehabilitation exercise. Furthermore, the interaction between the patient and the rehabilitation exercise should be more user-friendly and effective. To tackle these problems, a new series of clinical and home-based rehabilitation systems using enhanced virtual reality and serious gaming have been proposed [4]. This new rehabilitation scheme is commonly named as exergame.

Serious games designed for healthcare purposes relate to virtual simulations to train or educate patients via an amusing and enjoyable process [5]. In particular, exergaming relies on body movement tracking to measure health benefits. Regarding the rehabilitation purpose, some commercial gaming systems have been proposed. One of the first attempts to create interaction games was the Konami Dance Revolution™ game, released in 1991. However, the purpose of this game was neither fitness nor rehabilitation. In 2005, Yourself!Fitness™ was released by responDESIGN company with clear purposes of improving the health and fitness of the user. SeeMe™ was introduced to provide user-friendly tutorials for functional rehabilitation. In fact, these systems do not focus on basic gestures for rehabilitation. Moreover, there are no indicators provided for exercise monitoring. Reflexion Health (http://www.reflexionhealth.com/) has developed the first project focusing on the use of Microsoft's Kinect system to track patient adherence to the prescribed rehabilitation plan as well as to customize treatment to each patient and to review progress during visits. Recently, Jintronix (http://www.jintronix.com/) also proposed a complete system of rehabilitation using Microsoft's Kinect and the possibility of the therapist to choose the appropriate exercises. Research-oriented systems have been also developed. For example, robotic gait rehabilitation was developed and validated for chronic hemiplegic patients [6].

The objective of this technical note was to present a new real-time serious game system concept including a series of locomotion training exercises to improve the musculoskeletal rehabilitation of the lower limbs.

Real-time serious game system for functional rehabilitation

System overview

The development of a real-time 3D serious game system for functional rehabilitation of the lower limbs may be performed by using a generic development workflow (Fig. 1). This workflow consists of a 3D generic avatar generation, a subject specific geometrical registration process, a rehabilitation game playing and feedback visualization and control. These components are described in detail in the next subsections. Moreover, a system flowchart was also established to describe how the end-users interact with the system (Fig. 2). The system includes three different scenarios based on the user type (e.g. ''Administrator'', ''Expert'' or ''Patient''). When the user is an administrator, their main roles are to add patients and experts into the database. An expert is the user responsible for controlling the