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ORIGINAL ARTICLE /*Remote medical assistance*

Feasibility study of a serious game based on Kinect system for functional rehabilitation of the lower limbs

Étude de faisabilité d'un système de jeux sérieux basé sur le système Kinect pour la rééducation fonctionnelle des membres inférieurs

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Functional rehabilitation;
Serious game;
Musculoskeletal system;
Real-time monitoring;
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Kinect sensor;
3D computer vision

Summary
Introduction. — Conventional functional rehabilitation costs time, money and effort for the patients and for the medical staff. Serious games have been used as a new approach to improve the performance as well as to possibly reduce medical cost in the future for cognitive rehabilitation and body balance control. The objective of this present work was to perform a feasibility study on the use of a new real-time serious game system for improving the musculoskeletal rehabilitation of the lower limbs.
Materials and methods. — A basic functional rehabilitation exercise database was established with different levels of difficulties. A 3D virtual avatar was created and scaled to represent each subject-specific body. A portable and affordable Kinect sensor was used to capture real-time kinematics during each exercise. A specific data coupling process was developed. An evaluation campaign was established to assess the developed system.
Results. — The squats exercise was the hardest challenge. Moreover, the performance of each functional rehabilitation exercise depended on the physiological profile of each participant. Our game system was clear and attractive for all functional rehabilitation exercises. All testing subjects felt motivated and secure when playing the rehabilitation game.

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Discussion. — The comparison with other systems showed that our system was the first one focusing on the functional rehabilitation exercises of the lower limbs.
Conclusions. — Our system showed useful functionalities for a large range of applications (rehabilitation at home, sports training). Looking forward, new in-situation exercises will be investigated for specific musculoskeletal disorders.

MOTS CLÉS
Rééducation fonctionnelle ;
Jeux sérieux ;
Système musculosquelettique ;
Supervision en temps réel ;
Rééducation à la maison ;
Senseur Kinect ;
Vision 3D par ordinateur

Résumé
Introduction. — La rééducation fonctionnelle classique est coûteuse en temps et argent pour les patients ainsi que pour l'équipe médicale. Les jeux sérieux sont actuellement utilisés pour améliorer la performance et potentiellement réduire le coût médical dans le futur pour la rééducation cognitive et le contrôle de l'équilibre du corps. L'objectif de cet article est de réaliser une étude de faisabilité sur l'utilisation d'un nouveau système de jeux sérieux pour améliorer la rééducation fonctionnelle des membres inférieurs.
Matériels et méthodes. — Une base d'exercices de rééducation fonctionnelle a été établie. Les exercices de différents niveaux de difficulté ont été créés et implémentées. Une représentation 3D de chaque sujet a été créée. La caméra Kinect a été utilisée pour acquérir la cinématique des exercices. Un couplage entre cette cinématique et la représentation 3D a été effectué. Une campagne d'évaluation a été établie pour évaluer notre système.
Résultats. — L'exercice *squats* était le plus difficile à réaliser. La performance de chaque exercice dépendait du profil physiologique de chaque sujet. Notre système de jeux était clair et attractif pour tous les exercices de rééducation fonctionnelle. Tous les sujets se sentaient motivés et en sécurité pendant l'utilisation du jeu.
Discussion. — La comparaison avec d'autres systèmes a montré que notre système est le premier à focaliser sur les exercices de rééducation fonctionnelle des membres inférieurs.
Conclusions. — Notre système a une large gamme d'applications (rééducation à la maison, l'entraînement sportif). En perspectives, de nouveaux exercices seront développés pour les pathologies du système musculosquelettique.

Introduction

Functional rehabilitation is a common treatment and follow-up for musculoskeletal disorders [1,2]. Current routine practices have some drawbacks related to human resources and patient motivation [3,4]. Serious games have been developed and considered as a potential solution to improve patient motivation during the execution period of the functional rehabilitation program [5,6]. Recently, we introduced and described a new real-time 3D serious game system [6] to improve the motivation of the patients as well as to provide a solution for performing functional rehabilitation at home. Thus, in the future, serious games may contribute to reducing medical costs and human resources. In fact, serious game technologies have opened new perspectives to improve the current routine practices for functional rehabilitation of the musculoskeletal disorders.

In addition, the use of low-cost and affordable kinematic devices to monitor rehabilitation has been also investigated. Lozano-Quilis et al. [7] developed a system, called RemoviEM, for the rehabilitation of the balance control. This system used Microsoft's Kinect camera and captured image as subject representation. There was no virtual real-time interaction between the user and the system. In this study, clinical balance scales were used to evaluate the clinical effectiveness of the developed system. González-Ortega et al. [8] developed a computer vision system for cognitive assessment and rehabilitation based on the Kinect device. This system was developed for individuals with body scheme dysfunctions and left—right confusion. A successful monitoring percentage of 96.28% was noted for this system. Zannatha et al. [9] recently developed a stroke rehabilitation system for the upper limbs, based on the Kinect camera. Kinematics were also used to command a Nao robot to imitate the patient's movement. Muscle strength using electromyogram (EMG) signals was assessed to evaluate the effectiveness of the proposed solution. Another study conducted by Cho et al. aimed at performing proprioceptive rehabilitation [10]. The idea was to allow the patient to move a cylinder with his hand, and obtain visual feedback of this movement on the screen. The webcam has also been deployed as a very low-cost tool for specific rehabilitation processes. Scardovelli and Frère [11] used the webcam to create a very simple game for the rehabilitation