'VRComponent': a Virtual Reality Software for Neuro-rehabilitation with Robotics Technologies

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***Abstract*— Autonomous robots that are interfaced with virtual or augmented reality gaming are increasingly being developed to provide repetitive intensive practice to promote increased compliance and facilitate better outcomes in neurorehabilitation therapies. These therapist robots, equipped with a set of sensors and actuators for monitorizing the environment, allows health professionals to supervise the recovery of patients with serious disability. In this paper, a new system for supervising neuro-rehabilitation therapies using autonomous robots is presented. The therapy explained in this work is based on a set of virtual reality games developed by using robotics technologies, such as RGB-D camera and depth image processing. Three different virtual reality games have been developed in the application to gain better outcomes during the therapy, each one focuses on a typical exercise: 'Touch the apple', 'Follow the path' and 'Imitate the dance'. Both, the virtual reality games and the main robotics technologies for their development, are explained in this paper.**

I. INTRODUCTION

Current neurorehabilitation therapies are focused on regular physical exercises adapted for each patient and supervised by a health professional. Most of these exercises are based on imitating several motions that use different joitns ($e.g.$, to move an arm making an arc or to walk straight a distance). Other therapies focused on cognitive exercises are based on mental activities ($e.g.$, memory, judgement, abstract reasoning, concentration, attention and praxis) where the human interacts with the environment and the professional. Therapies that combines both the physical development of the patient and memory exercises are also common in the literature. Making such therapies with a specific robot, either replacing or accompanying the human therapist, offers patients an alternative to conventional therapy sessions.

The main goal of this paper is the development of a system that allows patients with serious disability to play three different games during a therapy session. These games have been developed in order to perform a physical and cognitive therapy supervised by an autonomous robot. In this novel therapy, the therapist robot projects three diferent games over a screen: 'Touch the apple', 'Follow the path' and 'Imitate the dance'. In the first one, patients uses their upper limbs for reaching a virtual apple. The second game is focused on gaining better outcomes in the recovery of lower limbs by doing patients to walk throug a path chosen by the professional. In 'Imitate the dance' game, the robot projects a dance composed of a list of motions and gestures that the human has to repeat. All these virtual reality games have options for increasing their difficulty level. The described therapy help work both the physical condition of patients, $i.e.$ by imitating the movements, and their memory, $i.e.$ by remembering the sequence of movements. The robot is equipped with a low cost RGB-D camera, and the sequence of images is analyzed for extracting and characterizing a set of human body features.

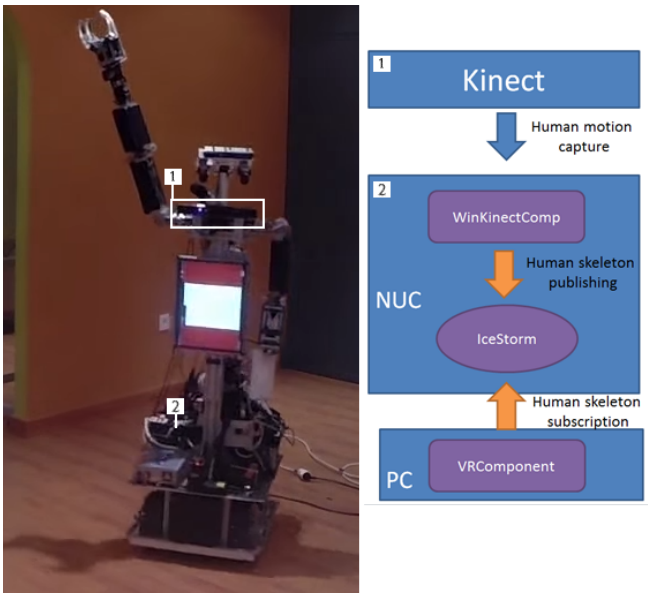

Fig. 1. Hardware and software architecture used in this work.

Similar approaches in the literature are VirtualRehab system [1] and Vitia Healthy Experience [2]. The first uses the Kinect and LeapMotion sensors to acquire data from the human body and hand, respectively, and use them for developing a set of virtual reality games. The Vitia Healthy Experience system is a closed-solution for a general rehabilitation, that is, this product is not focused on neurorehabilitation therapies. Both systems are commercial and expensive, and they don't offer healt professionals the possibility to modify anything from each game. On the other hand, there exist autonomous robots that perform therapies directly with patients. Ursus robot [3] is an autonomous agent developed by RoboLab, and it is designed to propose games to children with cerebral palsy in order to improve their recovery. Ursus has been used in real therapies in Hospital Virgen del Rocío from Sevilla, Spain, with excelent results [3]. In similar therapies, also with chidren with some kind of disability

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in their upper limbs, Nao robot has been succesfully used [4]. Both robots, Ursus and Nao, makes the exercises that children should imitate, and they are able to perceive the patients reactions and interact with them, modifying the exercises when they are not properly conducted.

This work is structured as follows: in Section II, a description of the virtual reality games used as threrapy is made in conjunction with the hardware and software architecture description. Finally, the main conclusions of this paper is presented in Section III.

II. VRCOMPONENT

A. Architecture software and hardware

Fig. 1 illustrates the robot ursus with the RGB-D sensors (Kinect style) marked on the picture. Currently, this robot has two different RGB-D cameras, but only those one marked as '1' is used for the therapy. In order to process the data acquired by the sensor and get a set of 3D points associated to the human body joints, Intel NUC is used. Finally, the human skeleton is then processed and showed in other PC where the health professional can access and modify the exercises. The hardware architecture proposed in this work is distribuited. Also in Fig. 1 is shown the software architecture of the system. The aplication is component-based programming, and use a publishing-subscription paradigm. Software is implemented using RoboComp [5] and IceStorm. Data from Kinect is processed by WinKinectComp, which publishes the human body joints. Then, VRComponent software subscribes to this specific topic and processed this data from each virtual reality game.

B. Virtual Realiy Games

Three different virtual reality games are developed in this work. For each game, the health professional is able to select their level of dificulty and then, adapt the therapy to the patient. Thus, a friendly graphical user interfaz is programmed where different variables are shown. In this section, a brief description of each game is presented.

- 'Touch the apple': In this game, the patient has to touch an virtual apple with their hands (left or right). The position of the apple in the 3D environment (distance to the human or its orientation) is automated, and it is dependent of the difficult ylevel.
- 'Follow the path': Here, the user has to walk throug a virtual path drawn on the ground. The shape of the path is automated, and also is dependent of the level of difficulty.
- 'Imitate the dance': In this game, a video including a dance is showed to the patient, who then has to imitate it. The type of dance can be chosen by the health professional depending of the difficulty level.

After each game, a general score is obtained by the patient. A high level in this value indicates that the human has achieved the therapy correctly. Fig. 2 shows the virtual representation of both, patient and avatars associated to each game. Fig. 3 illustrates the main windows of the application and its usage during some sessions.

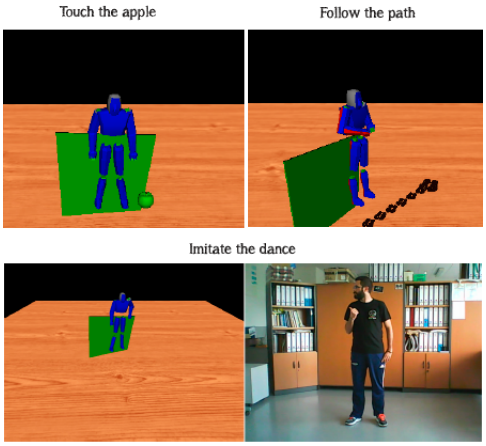

Fig. 2. Different views associated to each virtual reality game: 'Touch the apple', 'Follow the path' and 'Imitate the dance'

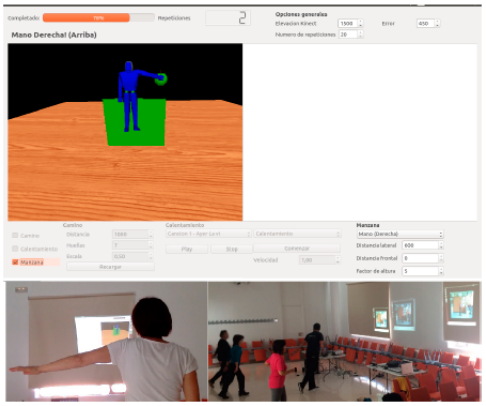

Fig. 3. Main window of the VRCompoment system. The application has been used in real therapies. On the left, the game 'touch the apple'. On the right, the game 'Imitate the dance'

III. CONCLUSION

This paper present a novel system for supervising neurorehabilitation therapies using autonomous robots. In the therapy, the health professional is able to choose between thee different virtual reality games, and also to modify their level of difficulty in order to adapt the exercise to the patient disability. This application is in an experimental phase, but it has been used with satisfactory results with real patients.

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