Ursus: A Robotic Assistant for Training of Children with Motor Impairments*

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Abstract. In this paper we present our results and work in progress in relation to the use of a social robot as assistant for training and rehabilitation in paediatric patients with motor disorders due to Hemiplegic Cerebral Palsy and Obstetric Brachial Plexus. The abilities addressed by a robot in the rehabilitation procedures without therapeutic contact include: active perception, sensor fusion, navigation, human movement capture, voice synthesis and plan execution, among others. We propose an ambitious approach to non-contact rehabilitation therapies with paediatric patients that present motor impairments, as well as an evaluation methodology to determine the effect of using social robots as therapy conductors. An experimental study was performed with six paediatric patients and results are explained. Finally, new challenges are exposed to develop in the future.

1 Introduction

During the last decade, the robotics community interest in social robotics has grown greatly [1]. Social robots are autonomous robots that interact with humans in daily environments, following human-like social behaviors (i.e. recognizing and expressing emotions, communicating, and helping humans or other robots [2]). The use of social robots has increased for a wide variety of applications (e.g., museum guide robots or assistance and rehabilitation robots). Specifically, rehabilitation robotics constitutes an emerging area of research, where the aim is to include robotics technology in the time-consuming and labour-intensive therapeutic process. As in other fields of application, robots can offer several key advantages, such as the possibility to perform (after establishing the correct set-up) a consistent and personalized treatment without fatigue; or decline its capacity to use sensors to acquire and record objective patient data, which can help to better quantify the recovery process. In addition, robots can also provide

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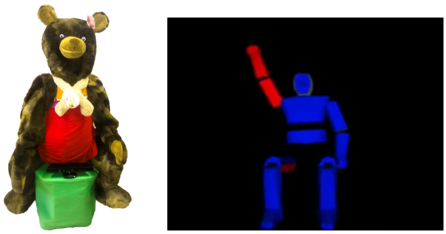
personalized motivation and coaching [3]. With the aim of building an innovative training model for therapy, this paper presents the development of a robotic platform for neurorehabilitation called Ursus.

2 Material and Methods

2.1 Robotic Platform

The robotic platform Ursus has been developed by the Robotics and Artificial Vision Laboratory of the Extremadura University with the collaboration of the Virgen del Rocío University Hospital. It is a low-cost platform which has the following characteristics: two robotic arms with three degree of freedom (DoF) and a robotic face and neck capable of generating simple emotions. The full platform is composed of 14 DoF, and is 140 cm tall. As is shown in Fig. 1, due to the type of patients, the robot embodiment was chosen similar to a teddy bear. In order to achieve a believable Human-Robot Interaction (HRI), different algorithms have been implemented in the platform using both, natural language and visual information. According to the natural language (*i.e.,* robot speech), Verbio Text-to-Speech system has been used. Besides, a synchronization algorithm between this TTS system and the robotic mouth has been implemented [4]. Finally, a most believable HRI was performed including neck motions associated to different commands and responses [5]. Currently, Ursus is equipped with only a PrimeSense *RGB-D* camera which acquires color and depth images. RGBD cameras allow the acquisition of reasonably accurate mid-resolution depth information at high data rates. In particular, PrimeSense RGBD sensor, is able to capture 640x480 registered image and depth points at 30 frames per second. Analyzing the sequence of frame *S* at each instant of time *t,* the robot, among other tasks, estimates the trajectories of the child's arm movements. The arm tracking is achieved according to the OpenNI software. Results of the algorithm are improved using a human being model, which allows to correct bad pose estimates [6]. Besides, the use of RGB-D information allows monitoring the scene, and thus to detect changes in the experimental scenario that could hind the performance, such as changes in the patient's attention.



(a) (b)

Fig. 1 a) The social robot Ursus; and b) register of patient's movements

2.2 Clinical Protocol Using Ursus

The rehabilitation treatment with Ursus is composed of two phases. In first phase, at beginning of each motor exercise, a video is projected with Ursus on a screen where a trainer shows how to do them. After watching the video, patient does the motor exercise that the robotic platform does it (Fig. 2a). If patient doesn't do the exercise, the robotic platform shows them how to do it. Furthermore, the robotic platform encourages patient, and digitally registers movements. In the second phase, Ursus projects games using augmented reality and record the patient's movements. In the Fig. 2b, a paediatric patient training with a game that used augmented reality. Concretely, patient has to pick up apples placed in strategy localizations for its training and store it in a basket.

(a) (b)

Fig. 2 a) A paediatric patient training with Ursus and b) Augmented reality game used for the experimentation

The clinical variables that are used for evaluation of the clinical evolution are: passive and active articular balance of the shoulder, elbow and hand; degree of concordance (i.e., the precision of the movements performed by the child with respect to the theoretical values established by clinical specialists); motor function of members (measured by "Nine Hole Peg Test") and the satisfaction of patients (measured using the Goal Attainment Scale).

3 Discussions

Despite the fact that Ursus integrates basic social skills, it is not able to generate non-verbal interaction cues (facial expressions) due to the physical limitations of its robotic face. Partially to overcome this problem Ursus can move its neck to generate basic gestures with the head. In the future, new tools will be developed and included in Ursus to enable a better interaction. Furthermore, although the motor training could be achieved using a tele-operated robot, patients usually prefer to interact with an autonomous robot. This implies that robots must be endowed with the perceptive and cognitive functionalities to allow them to operate as autonomous, active therapists. In this sense, the platforms will be able to detect and monitor people, merging information obtained from several types of sensors to recognize faces and interpret expressions (sad, happy) or gestures (body postures or static/dynamic arm movements). They allow Ursus to detect must emotional states and identify behaviours strengthen the child-robot interaction. These tissues are also trends for development in the future.

4 Results

On December 1, 2011, robot Ursus was used in real therapy at the Department of Rehabilitation of the Virgen del Rocío University Hospital. In this real experiment, six paediatric patients between the age of three and seven years old with upper-limb motor deficit from cerebral palsy or brachial plexus palsy performed a motor rehabilitation session using the robotic platform Ursus. The validation methodology of neuro-rehabilitation system based on non-contact robotics must to take into account not only the clinical variables, but also some kind of Human-Robot Interaction metrics that quantify the level of attention and engagement between the robot and the child. In this respect, firstly the results were qualitatively analyzed using different polls of all the participants in the experiment (paediatric patients, parents and technical and medical staff). These polls were conducted before and after the sessions and the answers were classified depending on the satisfaction level of the experience. The summary of these results is as follows: i) the physical appearance of the Ursus robot (i.e. robot's embodiment) was quite satisfactory; 2) patients enjoyed the rehabilitation session and they considered it more fun and motivating than only using the conventional treatment; 3) the medical staff also considered the rehabilitation session positive for the child's rehabilitation process, and the results achieved by the robot very useful for analyzing the evolution of the patients and planning personalized future rehabilitation sessions.

5 Conclusion

The combination of a robotic assistant and augmented reality seems a promising direction of research and suggests many new possibilities of innovation. A clinical study with six real patients from Virgen del Rocío University Hospital proved the benefits. Ursus provides to doctors a new system to objectively analysis the control of patients' evolutions. Moreover, patients with Ursus declared that enjoyed the rehabilitation session being more fun and motivating that conventional treatment. New lines detected in the discussion section will be challenges to develop in the future. In the end, faster recovery and better attitude towards the rehabilitation therapy are the goals that we are looking for and that we expect to achieve working along the lines presented here.

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