# 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.**

## I. 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 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 neuro-rehabilitation called Ursus.

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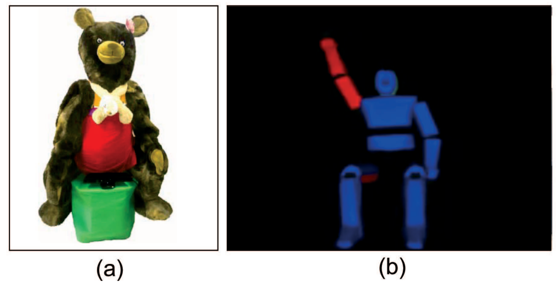


Fig. 1. a) The social robot Ursus; and b) register of patient's movements.

## II. MATERIAL AND METHODS

### *A. Robotic Platform*

The robotic platform Ursus has been developed by Robolab [1] with the collaboration of the Virgen del Rocío University Hospital. It is a low-cost design in which a static torso holds two robotic arms with five degrees of freedom (DoF) each, a three DoF neck and an articulated mouth. The head is 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 inspired in a friendly teddy bear. In order to achieve a believable Human-Robot Interaction (HRI) we have developed a cognitive architecture that integrates a robot behavior generation module, a patient modelling module and a conversational module. Different algorithms have been implemented in these modules using extensive use of both, natural language and visual information. For spoken language synthesis (*i.e.*, robot speech), the Verbio Text-to-Speech system has been used. Also, a synchronization algorithm between this TTS system and the robotic mouth has been implemented [4]. Furthermore, HRI was improved by including neck motions associated to different commands and responses [5]. Currently, Ursus is equipped with 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

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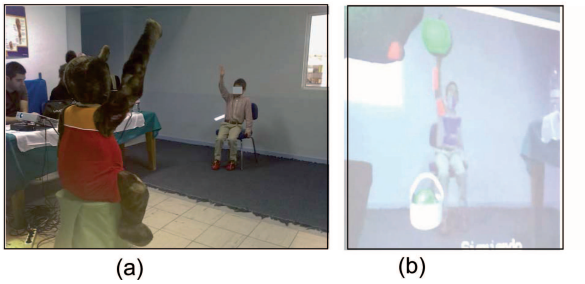


Fig. 2. a) A paediatric patient training with Ursus; and b) Augmented Relity game used for the experiment.

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.

### B. Clinical Protocol using Ursus

The rehabilitation treatment with Ursus is composed of two phases. In the first phase, at the beginning of each motor exercise, a video is projected by Ursus on a screen where a recorded human trainer shows how to do them. After watching the video, the patient is asked to do the exercise (Fig. 2a). If patient doesn't do the exercise, the robotic platform shows her how to do it. During the session the robotic platform verbally and gestually encourages the patient, and also records the movements. In the second phase, Ursus projects interactive augmented reality games on a screen in which the patient image is asked to reach certain objects placed strategically to force the therapeutic movements. In Fig. 2b, a paediatric patient is shown training with an augmented reality game. Concretely, the patient has to pick up apples placed in distant localizations for its training and store it in a basket.

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).

## III. DISCUSSION

Ursus has been tested so far in two occasions with the rehabilitation medical staff of the Virgen del RocÃ■o Hospital. The first time, the robot was presented to the clinicians after many design discussions and modifications in order to validate the final aesthetic and functional specifications. The second time, the robot was introduced in several rehabilitation sessions in which paediatric patients were performing their regular exercises. Parents were allowed to stay during the session. Although this short experiment by no means can provide rigorous data on the final utility of the robot as a therapeutic tool, important qualitative information has been obtained to guide the future development of this research. The level of acceptance by the patients, the clinicians and the parents was surprisingly high for an early prototype. This and other related information was obtained through polls as described the next section. From the point of view of the robot and its computational cognitive architecture, we have found that even more importantly than the physical capability to express emotions, i.e. facial and body degrees of freedom, the robot needs a better model of the patient he is dealing with. This model needs to hold an abstract representation of the body, the behaviour and the intentions of the child, that get instantiated online by the robot's perceptual processes. The more complete this model gets, the wider the repertory of actions that the robot will be able to exhibit in order to conduct the therapeutic session. A too simple model will fail to understand children behaviours such as running towards the robot to hug it or getting distracted and start looking at the window. Our current architecture maintains a simple model of the patient and combines it with the state of the robot and with the current goal to generate a stream of actions that the robot executes. The purpose of these actions is to reinforce or correct the patient behaviour during a complete rehabilitation session. More advanced models will be able to detect and monitor people, merging information obtained from several types of sensors to recognize faces and interpret expressions (sad, happy), meaningful gestures and speech. They will allow Ursus to detect emotional states and identify behaviours facilitating the child-robot interaction.

## IV. RESULTS

On December 1, 2011, the 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 the neuro-rehabilitation system based on non-contact robotics must 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, first the results were qualitatively analysed 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 ($i.e.$, robotâĂŹs 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 analysing the evolution of the patients and planning personalized future rehabilitation sessions.

## V. 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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