Robotic assistant for support in speech therapy for children with cerebral palsy

Vladimir Robles-Bykbaev*, Mario Ochoa-Guaraca*, Marco Carpio-Moreta*,
Daniel Pulla-Sánchez*, Luis Serpa-Andrade*, Martín López-Nores†,Jorge García-Duque†
*GI-IATa - Grupo de Investigación en Inteligencia Artificial y Tecnologías de Asistencia
Universidad Politécnica Salesiana, Calle Vieja 12-30, Cuenca, Ecuador
vrobles@ups.edu.ec,{mochoagua, mcarpiom, dpullas}@est.ups.edu.ec,lserpa@ups.edu.ec
† AtlantTIC Research Center
Depto. Enxeñaría Telemática, Universidade de Vigo
EE Telecomunicación, Campus Univ., 36310 Vigo, Spain
{mlnores, jgd}@det.uvigo.es

***Abstract*—Nowadays the World Health Organization (WHO) claims that one billion persons live in the world with some form of disability. From this group, an important number of children with disabilities and communication disorders do not have access to adequate services for special education or health care. In this point, it is important to mention that language and communication are mainstays in the development of several intellectual, social, and cognitive human skills. Therefore, in this paper we present a low-cost robotic assistant that is able to provide support for several activities that must be carried during the speech-language therapy sessions of children with different kinds of disabilities. This assistant is able to register patient's information (personal and clinical data), the results of therapy sessions, and provide remote support to conduct reinforcement activities at patient's home (using mobile devices). With the aim of determining the real feasibility of our system, we have carried out a pilot experiment in 73 therapy sessions with 29 children with disabilities (15 received traditional therapy and 14 received therapy with the assistance of the robot). The results show a rapid adaptation of children to the new tool and good results in phonological, morphosyntactical, and semantic areas.**

***Keywords*—Speech-language therapy; robotic assistant; cerebral palsy; children with disabilities.**

I. Introduction

Cerebral palsy (CP) is a set of permanent developmental disorders caused by abnormalities during the fetal brain development [1]. Types of CP are spastic, ataxic, dyskinetic, and mixed, being spastic the most common with an incidence of 70 to 80% [2]–[5]; this type of cerebral palsy causes the patient can not relax the muscles; therefore, this disease is the main cause of physical disability in children [6]; in addition to the physical difficulties, CP causes symptoms like disorders of perception, feeling, hearing, communication and behavior; even in chronic cases, CP may cause epilepsy and musculoskeletal problems [7].

According to the World report of disabilities, 15% of the world population suffers some type of disability that affects the functioning of the person. Despite these statistics, there is little information about children with disabilities in the world due to several factors such as: inadequate definitions of child disabilities, lack of statistical resources in some developing countries, and even the denial of children with disabilities in some families, however according to recent estimates by the World Health Organization around the world there is approximately 93 to 150 million disabled children between 0 and 18 years old [8], and about CP, its prevalence rate is approximately 2-4 in every 1000 children born [9].

Regarding education, 10% of children with disabilities have access to it and only half of them complete primary education [10]; furthermore, many children leave education due to lack of knowledge of teachers on how to include them in education plans [11].

About this reality, the field of robotics has been widely used as support agents for people with disabilities, with applications like automatic wheelchairs and even exoskeletons aimed to physical therapy [2]. On the other hand, a variety of robots for education and assistance in therapy have shown promising results in its pilot experiments [12]–[14]; under this premise, we propose the use of a robotic assistant in speech therapy, and we have done a pilot experiment to validate the effectiveness of this technology in the learning environment of children with CP. We also propose a system to generate reports for both the therapist and the children's parents; the aim of this system is that they can perform exercises at home as reinforcement therapies.

This article is organized as follows. In Section II some research related to the use of robotic assistants for therapy with children with cerebral palsy is presented. In Section III, the robotic assistant, its main functions, and software used in therapy is described. In Section IV, a therapeutic reinforcement system based on children's performance in previous therapy sessions is proposed. Afterwards, in Section V, the structure of the pilot experiment conducted and preliminary results obtained in order to validate the use of the robot in therapy are shown, and finally, in Section VI, conclusions and future work are presented.

II. Related Work: A brief overview

There are several studies where robotic assistants are used in therapy for children with CP to improve their physical, mental, and social skills. In this context, robotic agents may be humanoid and non-humanoid. Related with the humanoid approach [15] presents an experiment in which 4 children with CP are exposed to the humanoid robot NAO once a week over a period of 8 weeks. This approach demonstrated that its participants were more involved in therapies, and these became funnier and more productive; furthermore, it evidenced that this interaction promotes learning by imitation, specifically for control of the lower extremities and balance. Under the same approach [16] uses the same robotic agent, performing it a role of coach, the aim of the study is to measure the level of interaction and motor functions among 14 regular children and 11 children with CP. It is noted that children with cerebral palsy have a higher level of interaction; however, they have a poor performance in motor function compared to regular children.

On the other hand and regarding nonhumanoid robotic agents, in [17] a robotic arm that allows children with motor disabilities perform 3 sequences for specific tasks is developed. The system was used for 12 to 15 sessions over a period of four weeks, showing an increase in participation, expressive language, and interest from children in tasks that the robotic arm can do. Another study presented in [18] describes the NJIT-RAVR system which is a combination of robotics and virtual reality simulations for the rehabilitation of the upper limbs in children with CP. The main advantage of this system is an adaptive algorithm that allows that users with disabilities can fully interact in a virtual environment. Participants were trained in the system for one hour, 3 times a week for 3 weeks noticing a marked improvement in the kinematic measurements of their upper limbs. In [19] a robotic rehabilitation system for children with CP used after wrist tendon transfer surgery is described; the system consists of two robotic arms and a robotic wrist. The aim of the study is to determine whether the use of the robotic system is more beneficial than surgery alone.

The following studies are not focused directly on children with CP; however, they can demonstrate the efficiency of the use of robots in the interaction with children with disabilities. Wainer et al. [13] present a study performed with the KASPAR robot interacting autonomously with 6 children with autism spectrum syndrome during 23 sessions individually. The results have shown that children who interacted with the robot showed improvement in social behavior and collaborative skills. Lastly, Dickstein-Fischer and Fischer [20] present PABI, a humanoid robot that looks like a penguin with a variety of sensors and actuators enabling 8 degrees of freedom including eye, beak, head, and wings movements which allow it to express emotions and even maintain eye contact with children. In the pilot experiment with PABI it has been seen that children establish a bond with him.

Through all these studies the effectiveness of using robotic assistants in education, rehabilitation and therapy for children with disabilities has been demonstrated.

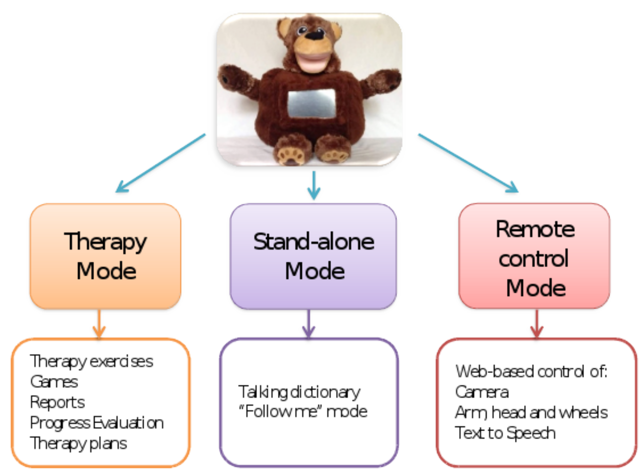
III. System Description

SPELTRA (Speech and Language Therapy Robotic Assistant) is a robotic system focused on providing support in speech therapy (see Fig. 1), its main function is the interaction with children through educational exercises and recreational activities, and indirectly assists the therapist in tasks such as: patient registration, user registration (therapists, administrators and superusers), therapy, activity log, performance evaluation of the patient, automatic report generation, and therapeutic reinforcements based on the individual performance of the patient.

The robot has several modules such as: a Raspberry Pi Model 2 B+ (which is the “brain” of all system), a resistive touch screen as visualization and interaction interface with the user, a speaker in order to reproduce useful acoustic stimuli for speech therapy also allowing the operation of text to speech conversion (TTS), a 5MP camera for face detection, a microphone for voice recognition used in standalone mode, 5 servo motors to allow the robot 4 degrees of freedom and finally a battery of Li-Ion to supply the entire system. These modules are intended to provide autonomy and sufficient ways to maintain a fluid interaction between the robot and the user which can be the therapist or the patient.

As can be seen in Figure 1, the system has three primary operation modes.

Fig. 1. Operation modes: Therapy mode, Stand-alone mode and Remote control mode.

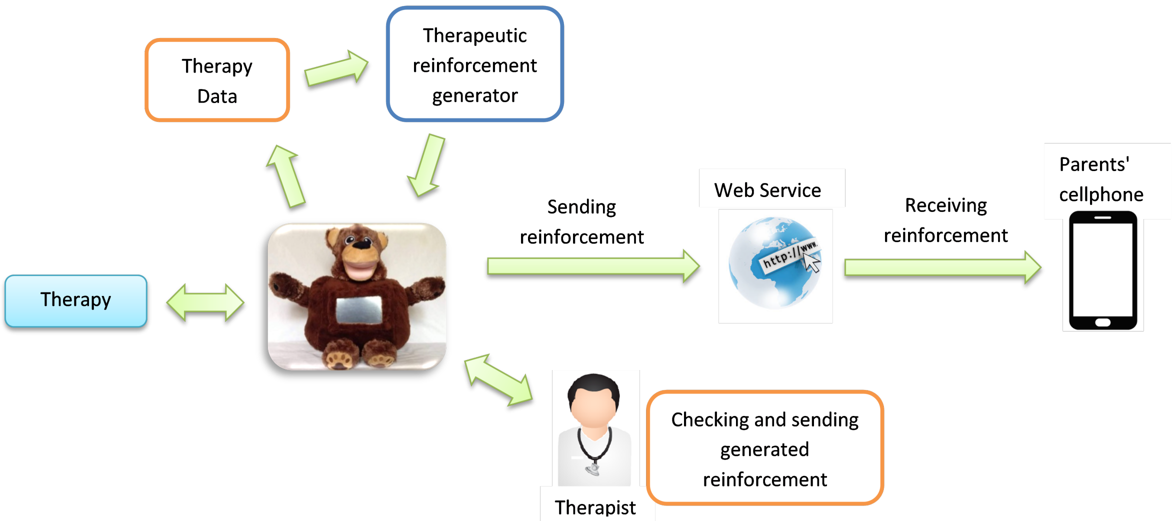


Likewise, the system provides report generation functions and reinforcement activities as seen in Figure 2.

A. Therapy Mode

In this operation mode, the robot displays on its screen some activities related to speech therapy such as phonological, semantic, and morphosyntactic exercises. These exercises are presented as a game in order to motivate the patient to perform them; once the children finish the exercise, their performance is evaluated and recorded in the database; with these data the

Fig. 2. Report generation system and mobile therapeutic reinforcement.



therapist is able to generate therapy plans manually or therapeutic reinforcement using the proposed automatic system in section V.

B. Stand-alone Mode

Using the microphone, camera, speaker, and touch screen, the robot can interact with it environment; so, it can receive acoustic, visual and tactile stimuli and react to them; the applications developed under this mode are a "Talking dictionary" and "Follow Me". The "Talking dictionary" is used to help the therapist; in this case, the therapist asks the robot a word's meaning, so it searches this word on Wikipedia. If that meaning is found, then it proceeds to read it. On the other hand, in "Follow Me", the patient shows a figure with a predetermined color facing the robot's camera and SPELTRA is able to follow the child wherever he moves following the figure, using its wheels motors.

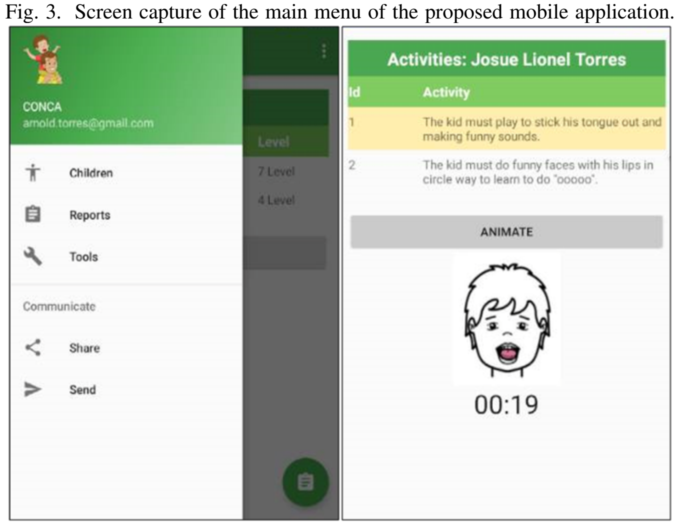
C. Remote control mode

Since the system has a wireless connection to Internet, in this operating mode, the robot deploys a server with a website through which you can use the interaction modules. The user can access through any device with a Web browser towards the IP address of the robot, and he is able to observe remotely the environment where the robot is placed. Other function in remote control mode is sending any text to the robot and it will speech this text through TTS module, and in the last function of the remote control the user can move the arms and wheels of the robot to interact with the patient. All these functions are useful in Gessel chamber to evaluate the level of interaction between the child and the robot remotely controlled.

IV. Therapeutic Reinforcement System

It is important that parents know their children's progress in therapy and that they become active members in their development; that is why the robotic assistant includes a mobile application (Android) to develop these activities. This application allows us to generate reports of the daily progress of the child during therapy, and propose additional exercises to be done at home. It is important to note that these reports will be generated by the robot, so they will have to be verified by the therapist and eventually be sent to parents. Parents will see these reports in the application illustrated in Figure 3, which will allow them to know the progress of their children and also perform complementary activities (at home) proposed as reinforcement by the therapist (this process is illustrated in Figure 2).

Fig. 3. Screen capture of the main menu of the proposed mobile application.



Some of the most important features of the mobile application are:

- Generates a complete report (daily, weekly, monthly or yearly) of activities and areas of language which the child has worked.

- Presents animations and clear instructions for reinforcement activities that parents should do with children at home.
- The therapists can consult quickly and dynamically children with whom they worked during the day and know the areas that need to be strengthened in order to plan their future work in class.

V. Pilot Experiment and preliminary results

The aim of the pilot experiment is to validate the use of robotic agent as an alternative way of performing speech therapy. Consequently, the performance of participants is evaluated by the scores obtained in each exercise and their interaction level in therapy to contrast with the results obtained by performing the same exercises manually.

Similarly, it is important to mention that before starting the evaluation process, to familiarize children with the robot's operation and appearance two sessions were held. These sessions only presented stimuli and movements generated by the robot, sounds, and how to display the contents on the screen (The issues of therapeutic evaluation part was not included).

The experiment focuses on the Therapy mode; therefore, 3 exercises related to speech therapy, specifically in phonological, morphological and semantic areas were made. We worked with 2 therapists from "Instituto de Parálisis Cerebral del Azuay" (IPCA) and 29 children with cerebral palsy and communication disorders, with an average language age of 7 years. These children were organized into two groups: a control group (15 participants) and another group who worked with the robot (14 participants). In total 73 therapy sessions were held in the three areas mentioned above. In order to avoid skew in the use of multimedia material, images containing the robot were printed and used with the control group.

Below we describe the most prevalent disabilities and communication disorders presented in the pilot experiment participants:

- Disabilities:
  - Infantile cerebral palsy, ICD-10 (International Classification of Diseases) Code: **G80**. Total of patients: **10**
  - Intellectual disability, ICD-10 Code: **F71**. Total of patients: **10**
  - Other disabilites: Attention-deficit hyperactivity disorder, predominantly hyperactive type, ICD-10 Code: **F90.1**, Convulsive syndrome: **G40**.
- Communication disorders:
  - Specific developmental disorders of speech and language, ICD-10 Code: **F80**. Total of patients: **15**
  - Dysarthria, ICD-10 Code: **R47.1**. Total of patients: **5**.
  - Other communication disorders: Delay of language development ICD-10 Code: unspecified.

In Figure 4 we can see a child with disability interacting with the robot with the assistance of the speech-language therapist.

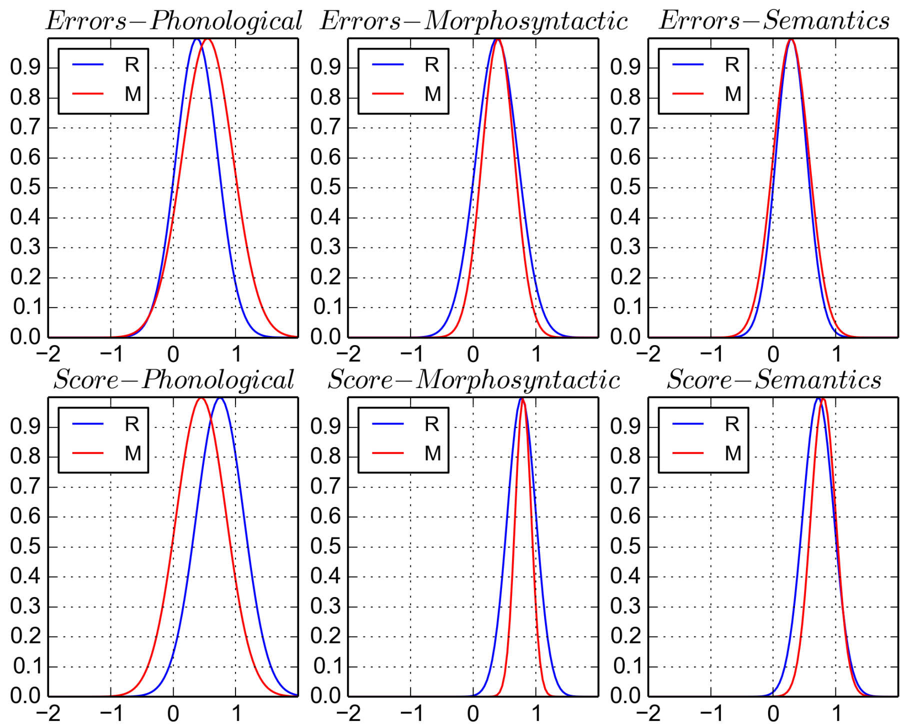
Fig. 4. Therapy performed at the "Instituto de Parlisis Cerebral del Azuay" IPCA, Cuenca - Ecuador.

The scores obtained in each case were evaluated. These scores will determine whether children perform better when they get therapy with the variety of stimuli that the robot can give versus manual therapy.

In Figure 5 we can see the results obtained with children after conducting therapy sessions. The "R" label shows that therapy was performed with the robotic assistant, while the "M" label indicates that the therapy is performed manually. Here is each of them:

- In the phonological area the children had a better score when working with the robot, since the average success has a higher value than that obtained with manual therapy. Similarly, we can see that the errors are substantially less, performing better with the support of robotic assistant. All this is due to the fact that acoustic and kinesthetic stimuli orders probably have a better effect on children in this area.
- In the morphosyntactic area very similar results can be noticed. This is one of the most complex areas for children with cerebral palsy and intellectual disabilities; due to it, concepts such as building meaningful sentences, employing relations grammatical and syntactical hierarchical structures are are adressed. However, in the score, it is seen that there is less scattering of data, which allows inferring that are closer to the average, so the overall average is higher in the case of the robot assisted therapy.
- In the semantics area, similar results are observed with a small advantage in the case of therapy conducted manually. At this point we consider that there are no significant differences between the results obtained by robot or manual therapy. It is important to notice that only in this case the score obtained by children with manual therapy is somewhat higher than the one that was achieved with the robot.

Fig. 5. The Gaussian graphics of errors committed by the children as well as the performance achieved in each speech-language area: phonological, morphosyntactic and semantic.



VI. Conclusions

This study has presented a complete support system for speech therapy for children with disabilities and communication disorders. This proposal allows to effectively integrate therapists, parents, and patients. The results obtained in the experimental plan shows that children are able to adapt quickly to the robot, and in the case of phonemic area, an immediate improvement in the results has been demostrated. Moreover, it should be noted that the robot can provide incentives that encourage children to make therapies more positively, while their appearance creates a bond between robot and patient.

As future work we propose the following:

- Build a virtual robot with the aim that parents can make the process of therapeutic reinforcement at home using a virtual intermediary (which will be similar to that used in the real therapy).
- Develop an artificial vision module that allows the robot to recognize everyday objects that are used during therapy sessions. Thus, the child (depending on the type of cerebral palsy) may receive a better visual and acoustic stimulus.

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