Development of a Wizard-of-Oz based framework for QTRobot to facilitate the learning of handwriting in children with dysgraphia

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Abstract

This article presents a framework for a companion robot aimed at facilitating the learning of handwriting in children with dysgraphia. The framework is composed by a Wizard of Oz (WOZ) interface, a library of social behaviors and a perception system. The WOZ interface has been realized as a web service via Flask for cross-platform use, controlling the robot through ROS. A robot behaviors library has been designed by integrating robot gestures, facial expressions, and speech. The visual perception of the robot exploited a RGB-Depth camera to recognize humans in terms of their skeleton. The presented framework is a prototype that will be evaluated in the field during long-term child robot interactions. This framework is represents a basic building block in the development of a semi-autonomous system for the training of handwriting and fine motor skills.

Keywords

Socially assistive robotics, Dysgraphia, Handwriting training

1. Introduction

Writing is an essential skill. Behind speech, it is the main means of describing things and expressing emotions. For most people, learning to write seems like a natural thing, but some children have real difficulties because of developmental coordination disorders (DCD).

DCD formaly called Dyspraxia[1] belongs to neurodevelopmental disorders (NDD) which usually appear in the early stages of development. The consequent deterioration in personal, social, academic or professional functioning results in characteristic signs.While pervasive in children with typical development, writing problems are frequently mentioned symptoms in children with DCD and autism spectrum disorders (ASD)[2] with deficiencies in fine motor tasks such as finger tapping or typical differences in grip, strength, and endurance of dysgraphia.

To further study how assistive robotics can positively influence writing training in dysgraphic children[3], the iReCheck project, a follow-up of the CoWriter project[4], aims at developing

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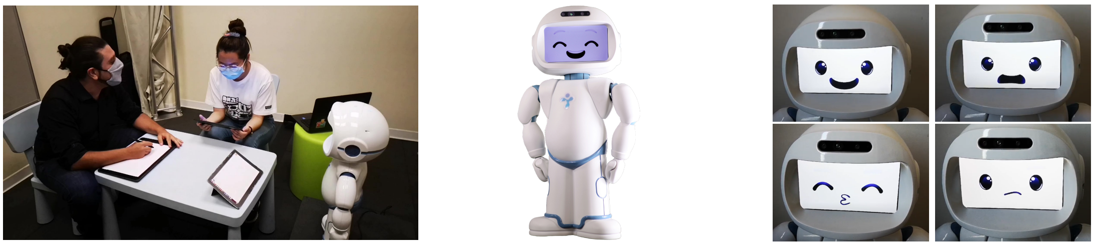

Figure 1: The experimental setup (left), the QTRobot (center) and its facial expressions (right).

a semi-autonomous robotic platform endowed with social skills able of explicitly taking in account the child and the caregiver presence in its perception-decision-action loop. Based on a "Learning by teaching" paradigm[5], the robot asks the child to play the role of a teacher while it plays the role of a student who seeks help to improve his writing[5].

In a typical scenario (**Fig 1**), the robot stands with its fake tablet, together with a caregiver, the child and her/his professional tablet, able to capture handwriting features. After the selection by the caregiver of a handwriting activity, the robot will pretend to write on its fake tablet with its hand. Corresponding signs will appear on the tablet. The child will then judge and eventually correct the robot's handwriting by writing next to it, providing a new sample. While the robot learns from such writing examples, in the presented scenario the children will lead the teaching: their self-esteem will be enhanced as they are no longer the ones being criticized. Moreover, in order to improve the robot's handwriting skills, the children should provide better samples and, while doing so, they improves, too. In accord with this hypothesis, by interacting with a non-judgmental robot having "writing difficulties", children will feel responsible for its improvements and its failures, motivating them on teaching, pushing them on providing better samples and, ultimately, in training their own handwriting skills[6]. Compared with the traditional handwriting training activities, the use of a small humanoid robot would make children comfortable and at ease: the simplified human-like embodiment of the robot will be able to provide simple, stereotyped, and clear feedback; at the same time, the non-judgmental nature of the companion robot will reduce the stress of children during the training.

This article focuses on the development of: (1) a library of simple social behaviors as basic building blocks for the social interactions of a CoWriter robot; (2) a Wizard-of-Oz interface offering the real-time control of the robot; (3) an embedded perception system aimed at capturing and logging children behaviors. The proposed system will have the double goal of experimenting and evaluating the behaviors of the robot while interacting with the children as well as providing caregivers with a robust, non-autonomous but ready-to-use handwriting training robotic system.

2. Materials and Methods

Luxai's QTRobot (**Fig 1**) was chosen as preferred social robot platform, in the hope of having expressive abilities in terms of social cues and, above all, broader facial expressions and better stability[7]. In terms of hardware, it integrates two PCs, a ReSpeaker Mic Array installed on its head and an Intel RealSense 3D camera on its forehead. Its face is a screen that can display various emotions of the robot in video format (**Fig 1**). The robot head allows for yaw and pitch rotation. Both arms are anthropomorphic carriers of 3 degrees of freedom. Besides, QTRobot's programming interface (API) aims to facilitate access to basic robot functionality by leveraging a set of user-friendly ROS interfaces.

To improve the quality of engagement in long-term child robot interactions[8], a variety of behaviors is needed. Complex behaviors contain gestures, emotion, and speech. Such behaviors can be consequently stored using their parameters, as the movement's angles, the speed, an emotion identifier, the content and the speed of speech. Fluid predefined movements were implemented by physically moving the robot's joint while recording the dynamic of their different positions and angles, exploiting the gesture API built-in with the QTRobot. A standardized file format for the behaviors has been developed, keeping the name, the speed of the gesture, a sequence of facial expressions and speech.

In joint work with expert clinicians from the developmental psychiatry service from Pitié-Salpêtrière medical hospital in Paris, we have established a library containing 78 behaviors grouped into 17 categories. These categories are divided into two tabs: the scenario and game tab and the reaction tab. In any case, to reduce alienating, repetitive behaviors and increase the robot's vitality, we have included several sentences with similar meanings for the same behavior. The program selects one at random when running.

Perceiving and understanding the behaviors of interacting children is an essential skill that a socially aware autonomous robot should have. At the same time, capturing and exploiting in online or offline analysis the behaviors of children while interacting can also refine and improve the interactive abilities of both the robot, by evaluating its behaviors, and the caregiver, by improving the social interplay. This can be done through the Nuitrack software, a 3D tracking middleware, a solution for skeleton tracking and gesture recognition. While integrated into the QTRobot APIs, through ROS messages, it was not integrated with the transformation management (TF) package. Consequently, Nuitrack data, including translations and rotation angles of 19 skeleton joints[1] for each person perceived relative to the camera, were exploited and translated in terms of TFs transforms: each TF maintained the relationship between the perceived coordinates and the robot frame, unifiying them into a single Cartesian space.

To test the behaviors of the robot in real use-case experiences, a Wizard-of-Oz controller has been built. The methodology behind a WoZ consists in the replacement of any automated decision algorithm from the robot's controller with the manual selection of the robot's behavior. During the interaction, the human "wizard" will remotely choose through a graphical interface the behavior that fits at its best the current state of the robot, of its surroundings and of the current interaction with its human partners[9]. The choice of this methodology translated in the implementation of a Wizard-of-Oz graphical interface of the robot, employed to control it while interacting with participants during the experiment. We designed two versions of the control interface: a debug interface, directed to technicians, that broadly exposes all the capabilities of the robot; a second one studied to fit the needs of caregivers during the training sessions with the children. While the debug interface simply displays a series of buttons, one for each behavior that can be executed by the robot, the caregivers' one has been then designed in more accessible way, following the ten usability heuristics for user interface design proposed by Jakob Nielsen [10].

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[1] Nuitrack skeleton: https://download.3divi.com/Nuitrack/doc/structtdv_1_1nuitrack_1_1Skeleton.html

QT behaviour controller

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Figure 2: The debug interface (left) and the version dedicated to caregivers (right).

3. Results

The **Figure** 2 shows some screens from the implemented interfaces. When the interface opens, a login page asking the user to enter the child's name. In the debug interface, buttons for each behavior will appear. Behaviors are divided into tabs, depending on the use case, and into different categories. The Caregiver interface **Figure** 2 is divided into two tabs: the games tab and the reaction tab. The games tab contains categories of behaviors that refer to the gaming scenario and on its advancement, as its beginning, its ending, its instructions[2]; the reaction tab contains the behaviors of the robot classified into categories identified by images. A double click on the category name opens a menu with the correspondents robot's behaviors. A behavior can be sent to the robot and executed by a further click on its name.

The **Figure** 3 shows us a comparison between the actual posture of a person interacting with the robot in the selected scenario and his skeleton as perceived by the robot's 3D camera. The proposed perception system is able to track in real-time the humans in the surroundings interacting with the robot. Notably, people data is synchronized with the robot's behavioral data. Figure on the right shows in particular two groups of markers: on the left the markers corresponding to the skeleton of the perceived person; on the right, the kinematic structure of the robot. Such synchronized data can be registered as a log and exploited offline for characterizing the social interplay between the robot, the child and the caregiver, as well as to track down correlations and causality events between them.

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[2] More on the tablet writing games: http://dynamico.ch/

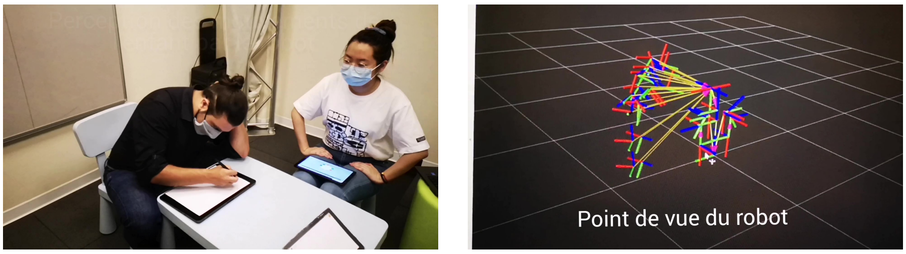

Figure 3: A snapshot from the experiment (left) and the robot's internal representation of it (right).

4. Discussion

The presented framework is ready to be employed by clinicians of Pitié-Salpêtrière medical hospital in handwriting training sessions of children with DCD. The developed behaviors as well as the WoZ interface will assure to caregivers the possibility of setting up effective training interventions based on the learning by teaching paradigm. On the other hand, the developed perception system allows the perception and the log of children behavioral data for further, in-deeper, offline or online analysis. We will focus, in particular, on engagement metrics that will be employed as practical measure to evaluate the effectiveness of the system. At the same time, the caregiver experience will be evaluated through usability tests like SUS or AttrakDiff[11]. In accord with the obtained results, improvements of the robot's behavior library and control interface will be developed.

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