Inclusive Robotic Environment for Teaching

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Abstract. *The inclusion of children with disabilities in education is a special challenge since they require specialized tools and personal. One possible approach to address this problem is assistive robotics, which enables these children to interact with the world. This paper proposes an inclusive environment for teaching based on low-cost robots to help teachers and students with or without disabilities to use robot technology.*

1. Introduction

Among the several problems faced by education, the inclusion of children with disabilities presents a special challenge, since such children require specialized tools and trained personnel. The Brazilian Scholar Census states that 752,305 special students were enrolled in public education in 2011, and in 2012 this number grew to 840,433 [Brasil, INEP 2013]. Thus, it is clear that the research on assistive technologies (AT) is becoming increasingly necessary. In the case of children with severely motor impairments, the lack of innate ability to move hinders their interaction with the environment, objects and living beings, thus discouraging them to develop not only technical skills, but also social and emotional abilities [Cook and Howery 1999]. This difficulty may expose these children to the feeling that they are unable to accomplish tasks by themselves, which may inhibit their learning.

One possible approach to address this problem is assistive robotics, a steady growing research field which provides an interesting and motivating scenario for learning [Kronreif et al. 2005]. The use of robotics in education is not novel and it is known for being multidisciplinary, encouraging teamwork and promoting real feedback in an exciting and motivating manner [Avanzato 2000]. There is also research suggesting that children can regard robots as living beings [Turkle 2007] – even though such kind of robot is still out of reach with current technology – which may help to create interesting interaction scenarios between children and robots to foster education. However, the high cost of robots sometimes forbids their use in the classroom.

In this sense, the Group of Integration of Intelligent Systems and Devices (GISDI) have developed initiatives that are low-cost, flexible and aligned to education. Furthermore, supposing children may be able to see robots as artificial living beings, GISDI has proposed an attractive robot for disabled children that present autonomous pet-like behavior [Ranieri et al. 2012]. Thus, this paper proposes that low-cost robots with some autonomous behaviors may improve human-robot interaction (HRI) helping teachers and students with or without disabilities to use robot technology.

2. Proposed Inclusive Environment for Teaching

The proposed inclusive environment for teaching will provide means of controlling the robot for the children, even if they present some kind of disability. Different from traditional robot applications that uses computer keyboard and mouse, the proposed environment considers two different human-computer interfaces (HCI): a hybrid sensor combining a surface electromyography (sEMG) and accelerometer sensors, and speech recognition provided by Google. The robot control and speech recognition is executed by a computational base, which can be either an entry-level personal computer or a smartphone. Figure 1 illustrates how the environment is composed and how the information flows through the system.

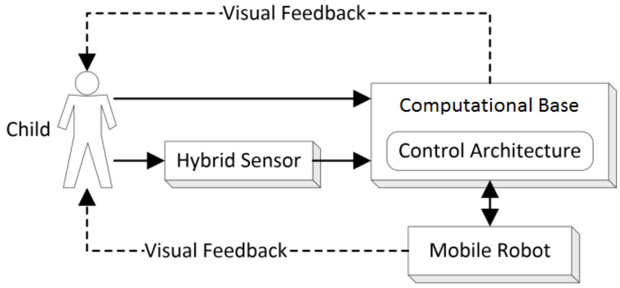

Figure 1. Proposed inclusive environment for teaching.

The goal is to have a child to control the robot by conveying commands through the HCI while receiving feedback from the robot's body and from the computational base's screen or speaker. Children without speech impairment can use speech recognition for this task, and may use a wireless headset to increase audio quality and ease the audio processing. On the other hand, children who are not able to speak clearly and cannot properly control arm movements can use the hybrid sensor developed at Ufes [Valadão et al. 2011], shown on Figure 2. If the child can control a given body part (e.g. head, arms or legs), the accelerometer can be attached to this body part to translate its movements into commands, and the sEMG can be used to translate muscle contraction into commands.

Figure 2. The hybrid sensor with the electrodes.

Speech recognition, as well as data processing, will be performed by the computational base, which can be either a PC or a smartphone. This project focuses on the smartphone with Android as the computational base, since it is relatively low-cost and provides several devices which can be used on the robot, such as: audio input and output; touchscreen to show "faces" or icons to communicate the robot's state to the child; and wireless communication capability. In addition, Android operating system is used on several devices from different manufactures. It also provides free development tools, and has a growing developer community that contributes with reference materials and computer libraries.

The communication between all devices (hybrid sensor, computational base, and robot) is based on Bluetooth. The sensor data, be it from the hybrid sensor or the headset, will be sent to the computational base, which is responsible for implementing the robot's control architecture. The control architecture reads the child's commands and the robot's sensors to decide on how to move the robot. If no command is received from the child, then the control architecture may move the robot around autonomously, following some navigation parameters. However, if a command is given, the robot may obey it, except if such command leads it to a dangerous situation, such as fall or collision.

The child's commands triggers predefined behaviors that moves the robot on the desired direction. The robots used on this project, shown by Figure 3, are detailed by [Ferasoli-Filho et al. 2012] and costs around USD 80.00. With them, the child is able to guide the robot through a maze, collect objects, draw on the ground, or simply play with the robot. Besides the visual feedback from the robot's body, the child can see the robot state – or simulated "emotion" – through a face showed by the smartphone screen, and can hear sounds produced by the smartphone speakers, such as synthetized speech.

(a) (b)

Figure 3. Roburguer (a) and 14-bis (b) robots.

3. Application

3.1. Hybrid Sensor

To experiment the hybrid sensor, an application for controlling a mobile robot was developed and tested with the 14-Bis robot. This application was designed supposing that the hybrid sensor is fixed on the user's head, whose inclination may provide commands for the robot control. There is also a graphical user interface (GUI), also controlled by the hybrid sensor, which provides some options concerning the robot assisted control. By tilting his head back, the user switches between dealing with the robot or the GUI. When controlling the robot, the linear velocity is proportional to the frontal inclination angle of the user's head, and the angular velocity is proportional to the lateral inclination angle. To improve the precision of hybrid sensor, a calibration procedure precedes the interaction activity.

When the child is not moving the robot, the robot's control architecture, which is based on a hybrid model consisting on three layers, moves it autonomously. In the implemented control architecture, illustrated in Figure 4, the deliberative layer, called pilot, is responsible to convert the child movements into commands – thus, the deliberation itself is not autonomous, as it is done by the child. Following the principle of keeping the child in control, the deliberative layer controls the system most of the time, except on the occurrence of certain events. The arbitration layer is responsible for monitoring the robot state, switching to the reactive layer when such events happen, and switching back to the deliberative layer once the behavior ends. The reactive layer adds autonomous behaviors to the robot, all of them with short duration: hunger, fear and wander. Hunger behavior is triggered when the battery level is low, and consists on a predefined sequence of movements. Fear behavior is triggered when the robot is driven to a dangerous situation, characterized by data provided by infrared proximity sensors on the robot, and consists on retreating and stopping for a while, giving the idea that the robot is scared. Wander behavior is triggered when the child does not give any command to the robot for a while, and consists on short random movements, intended to drive the child's attention towards the robot.

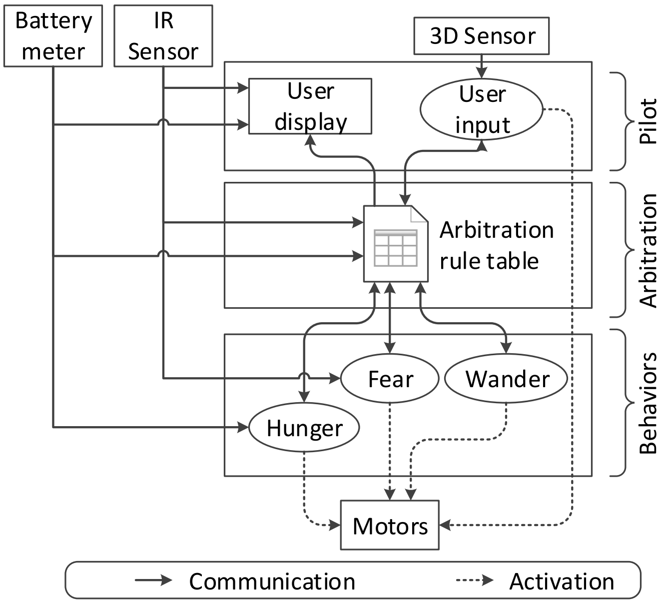

Figure 4. Control architecture for hybrid sensor application.

3.2. Speech Recognition

Speech recognition may improve human-robot interaction serving not only as an assistive tool to include impaired children into activities, but also as a useful tool for education of children without impairments. Due to the wide range of possibilities, the system using speech interaction is not focused on a specific application. Instead, an open system, provided with a flexible architecture, was developed. The robot used on the preliminary tests is Roburguer. The environment behaves as the following: the robot wanders around the environment while searching for a face and avoiding obstacles. When a face is found, the interaction using simple voice commands starts and will last until the user asks the robot to stop. The interaction will also be suspended if the user stops interacting or if some problem occurs with Google's speech recognition service.

The control architecture follows the principles of the subsumption architecture proposed by Rodney Brooks [Brooks 1986], which is a reactive control architecture [Matarić 2007]. The system implements behavioral modules arranged hierarchically in levels of competence, each comprising a control subsystem. The higher the level of competence, the more specific is the system defined by it. A level of competence can suppress inputs or inhibit outputs of lower levels. Figure 5 illustrates the subsumption architecture model. The system developed was based on four levels of competence: avoid obstacles, wander around, seek faces, and speech interaction. Each of them defines a behavioral system with increasing level of specificity. This structure can be adapted or expanded by modifying the behaviors within the levels or by including new levels.

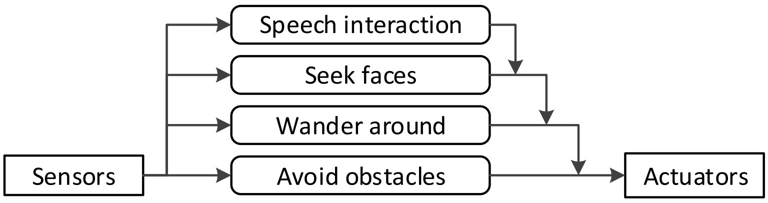

Figure 4. Control architecture for the speech interaction application.

4. Final Discussion

Robotic applications for education usually rely on traditional computer interfaces to control or program a mobile robot, as the environments presented by Aroca et al. [2012], Cruz et al. [2009] and Gomes et al. [2008]. To allow disabled children to use such applications, off-the-shelf AT must be used to adapt them to the children needs. However, if the inclusion of children with disabilities is considered while designing an application, then the resulting product could be easier to use than an adapted product.

Based on this idea, this project proposes a teaching environment that considered the inclusion of children with severe motor disabilities during the project's conceptual stage. Therefore, the resulting application provides different means for controlling the mobile robot, which does not rely on a single interface, such as the computer keyboard or mouse.

Other goal of the proposed inclusive environment is being low-cost and flexible, which led to: the adoption of entry-level PC or smartphone as the computational base; the employment of hybrid sensor; and the use of different robots – at this point, Roburguer and 14-bis. This may ease the replication of this environment on schools, since it can make use of available infrastructure.

At this moment, the environment provides an entertainment robot that can be used for teaching geometry and basic algorithm notions, as well as a toy for motivating children.

By incorporating simple behaviors, the robot actions are not completely predictable, thus drawing children attention as an artificial pet. Hence, it is expected that the addition of the mobile phone can expand the child-robot interaction effectiveness by adding the capabilities of speech and of displaying emotion icons through its display.

In future works, computer interfaces will be improved to ease the configuration process for the end-user. In addition, the proposed environment will experimented at one inclusive school to evaluate its efficiency as a learning tool and as a social inclusion strategy.

Acknowledgements

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