A Friendly Mobile Entertainment Robot for Disabled Children

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***Abstract*— Disabled children, when compared to other children, have fewer opportunities for exploring and interacting with the world. Thus, they are exposed to the feeling that they are unable to do anything by themselves. In this sense, the use of mobile robots may help these children to overcome their limitation and provide means to develop social skills. This paper describes partial results of on-going research on control architectures for mobile robots concerning hardware and software aspects. We propose a behavior-based architecture for the interaction between humans and robots, particularly children with severe motor disabilities. The main goal is to create a modular, flexible and scalable development environment, which motivates children to interact with the robot and the world.**

Keywords—mobile robot, control architecture, assistive robotics, children with severely motor impairments, smartphones.

I. INTRODUCTION

It is not hard to conclude that environmental exploration is a very important phenomenon to children. By interacting with the world and other life forms (from trees, to pets, to people), a child can develop not only technical skills, but also social and emotional abilities [1]. Children with severely motor impairments, however, have fewer opportunities for such exploration and interaction, which exposes them to the felling that they are unable to do anything by themselves. One approach which has raised good results on aiding these children is robotics. Although there are certainly other manners to achieving the same goal, robotics provides an interesting and motivating playful scenario of its own [2].

Besides the obvious capability of moving objects around at the order of the child, robots present themselves more than a ludic toy: they can be perceived as artificial living beings. Of course, to date certainly there is not a single robot which may be understood as “alive”, and there is no proof that they may gain “life” and conscience someday. However, there is research suggesting that children can regard robots as living beings [3]. The popularization of robotic heroes in children books, comic books, video-games, animated cartoons, and so on, may have helped children to develop an empathic opinion towards robots. In fact, [4] suggests children can draw robots with human-like characteristics and invent stories portraying them as living beings.

Believing children are able to recognize robots as artificial life forms, we already addressed the problem of creating an attractive robot for disabled children and enabling such robot to present autonomous pet-like behavior [5]. Other pursued goal is to create low-cost equipment, as this kind of initiative should be replicated in diverse regions over the country in many hospitals, clinics or non-governmental organizations.

The proposed robot’s goal is to act as the medium between a child with severely motor impairments and the environment. Thus, the robot will perform tasks such as moving objects around as commanded by the child. In order to extend its capabilities, while maintaining the low-cost ideal, we propose the adoption of mobile phones with modern operating systems as the embedded processing device. Some features introduced by mobile phones include speech recognition and synthesis, graphics display, wireless communication, and so on. Hence, this paper describes the proposal of an entertainment mobile robot endowed with human-like expression, which is attained with the use of mobile phones.

Nonetheless, it is important to note that this robot can be used in other educational scenarios, since it was developed with the concepts of universal design in mind. Therefore, children without disabilities can also make use of the proposed entertainment robot.

The following sections will cover the robot design and assistive technology concepts, the contribution of mobile phones to robotics, the proposed global system, the proposed control architecture, the software architecture and, finally, the expected results concluding remarks.

II. ROBOT DESIGN

In general, a mobile robot project is strongly related to the work the robot is supposed to carry on. On the one hand, the more detailed is the application, the easier is the project conception. On the other hand, when the application is wide, with uncertain objectives, the proposed versatility allows and encourages new development scenarios. In other words, when a given application is met, new ideas emerge, and it is important that the project basis is reusable, reducing the effort to attend the new idea. In this sense, mobile robotics demands an architectural flexibility which allows the reuse of previous work and provides, at the same time, encouragement for developing new applications, reducing the effort and the development time demanded to build new robots.

At the same time, the mobile robot may be required to serve a wide user audience, from children to adults, with different body size and shape, which may have debilitated health or some kind of circumstantial difficulty. Universal Design addresses the problem of developing a product or environment to serve the largest number of people of all ages and abilities, thus, promoting the inclusion of all people on the whole human activities [6]. Obviously, it is a difficult task to develop a product that attends to all people in all circumstances, thus Universal Design should be understood as a process with the goal of addressing most of its principles and goals [7].

To incorporate Universal Design, robots dedicated to children should consider some project aspects that address the appropriate dimensions and physical form, the colors and textures, the materials, the communication characteristics, the behavior and so on. In the case of children with special needs, some cited aspects may be favored or even suppressed. At a certain moment, different colored lights flashing in a given frequency may encourage the interaction between the child and the robot; on the next moment, only the lights or the frequency may be relevant. The most important is that the control architecture project contemplates not only these scenarios, but also accepts changes without demanding large efforts.

In this same way, the hardware flexibility must follow the same ideals. The use of new technologies, with simple and low-cost features, may contribute to the development of this and another robotics application areas [8]. One of these new technologies is the cell phones with modern operating systems – the so called *smartphones.*

III. SMARTPHONES IN ROBOTICS

Originally created to be used as advanced personal assistants, smartphones have increased its relevancy on the market, expanded its functionalities, improved its connectivity and energetic efficiency, and had its cost reduced. In general, smartphones converged to a minimum set of devices, which are available within its hardware architectures. Each one of these devices provides a capability to be explored in assistive robotics. This minimum set of devices and its applications will be discussed as follows:

- *Processing unity*: since modern mobile operating systems require considerable processing power, all smartphone provides an embedded processor. The processor capabilities can vary from slow, single-core with low clock-rate units, to fast, multi-core with high clock-rate units, allowing the user to employ a device which have the an adequate processing unit.
- *Display:* all current smartphones feature a LCD (Liquid Crystal Display) or AMOLED (Active-Matrix Organic Light-Emitting Diode) display, capable to show colored pictures to the user. These displays may be used to provide information concerning the robot, as well as to display a virtual face whose expression refers to the behavior or status of the mobile robot. This approach was used by [9] for addressing child-robot aesthetic interaction, and can also be used to imitate the head expressions used to communicate with autistic children as in [10] and [11].
- *Touchscreen:* consists on the most common smartphones' interface and usually provides a capacitive display able to track, with precision, one or more fingers in contact with the screen. Hence, this device is generally used as interface to menus. However, it can also be used to track tactile events on its surface, which may help autism therapy in a similar fashion as presented in [12].
- *Camera:* most smartphones are equipped with a high quality rear-camera. Some models bring, also, a lower quality frontal camera. These cameras may be used for navigation means, to allow objects recognition inside an arena, or to recognize the user face or emotions.
- *Accelerometer:* allows the smartphone to track its spatial orientation through the Earth electromagnetic field influence upon the sensor. Besides of serving as a data source to the robot inertial navigation system, the accelerometer may be used as a direct interface to control the robot. In other words, the user can use the smartphone do move the robot through its orientation on the space. This can help children who do not have hand dexterity to move the robot using some other part of their body that they can effectively control.
- *Audio:* smartphones are provided with an audio input, through a microphone, and an audio output, which allows the user to record and play sound stimuli. Concerning robotics, such sensors are of great interest, serving as a user speech interface. Some operating systems, such as Android, provide support to speech recognition and synthesis in many languages.
- *Wireless communication:* besides the mobile phone common protocols, such as GSM or CDMA, smartphones in general provide two standard communication means: Bluetooth and Wi-Fi. Some models also provide other protocols, such as NFC (Near Field Communication) and IrDA (Infrared Data Association). Among these, the most interesting, concerning robotics, are Bluetooth and Wi-Fi, which allows the connection between robots and computers that serve as a remote processing base.

This set of devices can improve the robot hardware by providing new sensors and actuators, besides providing a versatile processing unit. Thus, we propose its application in an entertainment mobile robot.

IV. PROPOSED GLOBAL SYSTEM

The Global System developed in this work allows the child to convey commands to a robot using a myoelectric (EMG) and movement sensors placed on the child's body. As children with severely motor impairments have little control over arm movements, we proposed the usage of head movements and any muscle contraction to control the robot.

The sensor data, which acquires information on the body inclination and muscle contraction, is transmitted through a wireless connection to a computer embedded on the robot. This computer will determine if the robot will follow the child's order or if it'll interact with the child.

The data is transmitted to the robot embedded computer through a wireless Bluetooth communication; at the same time, the robot hardware also transmits its sensorial data to the embedded computer via a Bluetooth connection. The embedded computer is responsible for controlling the robot and thus embeds the robot's control architecture. The control architecture arbitrates over the child movements and the robot sensors to actually move the mobile robot. Hence, the robot actions are seen by the child, who can maintain the current command or change it in order to drive the robot to its goals. The children can also see the robot state – or simulated emotion – through the smartphone screen, which may show an anthropomorphic face, or sound. The child can also interact with the robot by touching its face. The Fig. 1 shows this system, as well as the information flow.

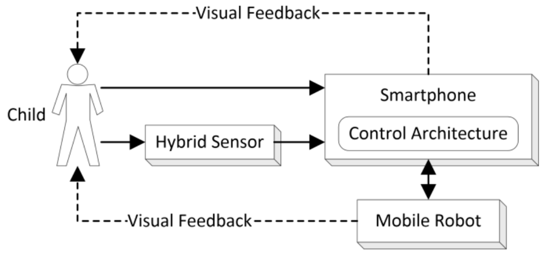

Figure 1 – Proposed global system.

A. Hybrid Sensor

To acquire the movements of children, a hybrid EMG sensor and accelerometer, developed by [13], was used. The smartphone could be used to monitor the child movements; however, adopting the hybrid sensor can yield better results due its small size and weight – besides, it provides the EMG sensor. The hybrid sensor is shown on Fig. 2.

Figure 2 – The hybrid sensor with the electrodes.

While the EMG captures information about the extension of a voluntary muscle on the child's body, the accelerometer determines the orientation of the child's head. The muscle data may activate or deactivate a robot module, such as a pen do draw on the floor or a grabber to move objects around, and the inclination data may be used to drive the robot.

B. Mobile Robot

As discussed, the smartphone will control the robot through a Bluetooth communication link, which is the same used to receive the hybrid sensor data. Besides, the user will be able to check the robot state though "faces" shown in the display and sounds emitted by the speakers. The user will also be capable of interacting with the robot through touches on the screen. The robot camera will be used, in a first moment, to support the navigation and to recognize some contrasting colored object, while the accelerometer will be used to inertial navigation.

Concerning the operating system, we propose the use of Android, which is an open source operating system embedded in many smartphones of distinct manufacturers and with different prices. It means that an application developed to a specific model may be easily ported from one device to another, because it allows the development of applications that doesn't attach the robot to a specific product.

Concerning the development, Android can be placed as a promising platform, because there is a strong developer community which drives the conception of support documentation, creating a knowledge base which encourages new applications' development. Besides, the operating system has a complete and free development environment, and libraries that cover from speech recognition and synthesis to digital image processing.

A picture of a robot prototype is shown in Fig. 3. The robot is based on the mechanical system used in Roburguer robot [5]. This prototype is equipped with a differential drive system composed of two continuous rotation servo-motors, and a frontal "grasper", also driven by a servo motor, which enables the robot to move small objects in the environment. Over the robot was placed a smartphone, which has its angle adjustable by another servo motor. A variation of this angle allows the change of vision on objects and paths taken or sought, and recognition of symbols and facial expressions. The size and mobility conferred by the mechanical system allow development to occur on a worktable. As the robot is not heavy either, it dispends little energy during its displacement, compared to its energy storage capability (batteries). Once recharged, the robot can be used for 1 to 4 hours, depending on the activity performed. The connections appearing in the figure are related to the motors and to the development board.

Figure 3 – Robot prototype with an embedded smartphone.

V. Control Architecture

The robot autonomy is a desirable feature, since it may encourage the collaborative work between humans and robots. In this sense, a behavior-based architecture may support the presented aspects [5]. Hence the robot can be endowed with basic behaviors, which characterizes itself as a pet that follows its owner in some educational or ludic situations. Therefore, the robot autonomy enables a scenario that can create a more natural social relation, opening a wide research perspective in protocols and ways of communication that answers different cases [14]. To a given situation, possibly, speech may be a desirable interface. At another, gestures or expressions may be preferable. That is the reason which motivates proposal of a control architecture with the cited attributes.

A modular, flexible and scalable control architecture is object of interest to many research groups [15]. In some applications, such as assistive robotics, this interest is enhanced due to the interaction between different knowledge areas, besides those related to technology. It means that the architecture cannot be another obstacle to the project, but facilitate and encourage the development due to the providence of an architectural organization.

The modularity is given by the division of competencies of the control architecture, which we divided on three-layer control architecture. The first layer, responsible for the navigation and control of the motors and sensors, concerns realization and maintenance. This layer itself ensures that the robot can walk in a straight line, follow a wall or a line in the surface or avoid obstacles, for example. The intermediate layer, named "arbitration", aims to determine which module will control the robot. Finally, the third layer is responsible to give autonomy to the mobile robot, being called deliberative. However, in the present system, the deliberation is made by the user, provided with an appropriate interface.

As shown in Fig. 4, the three layers denominated "Pilot", "Arbitration" and "Behavior" work together. Through the inertial sensor and the human-machine interface, the user transmits to the *pilot* layer his/her intention. The user intention is, therefore, propagated to the *arbitration* layer, which, based on the user and the robot data, decides if the user's intention will be concretized or if a *behavior* of the lowest layer will be activated.

In this application, the arbitration is made through a table of well-established rules. In other words, there is a priority order between the pilot and different behaviors that can control the robot. The *fear* behavior, which will be presented next, has priority over the *pilot* layer, which, in turn, has priority over the *wander* behavior. This structure was chosen because it is simple and sufficient to a preliminary work.

The lowest layer is responsible for the behaviors. Three basic behaviors are implemented: *hunger*, *fear* and *wander*. *Fear* takes control if one sensor detects that the robot entered a prohibited region. The reaction is to signalize that the robot is "scarred" by showing an appropriate face on the smartphone display, paralyze the robot for a few seconds e retrocede the movement, leaving the "dangerous" surface. *Hunger* is activated when the battery level becomes lower than a certain value. The robot reacts by reducing its speed and showing, on the display, a face which expresses tiredness. After a certain period of stimulus absence, *wander* behavior is activated, with the objective of calling the user's attention. This behavior consists on the realization of random movements, for few seconds, while the robot emits sounds similar to whistles.

The following section will discuss how will the embedded software be comprised and discuss the implementation of the control architecture.

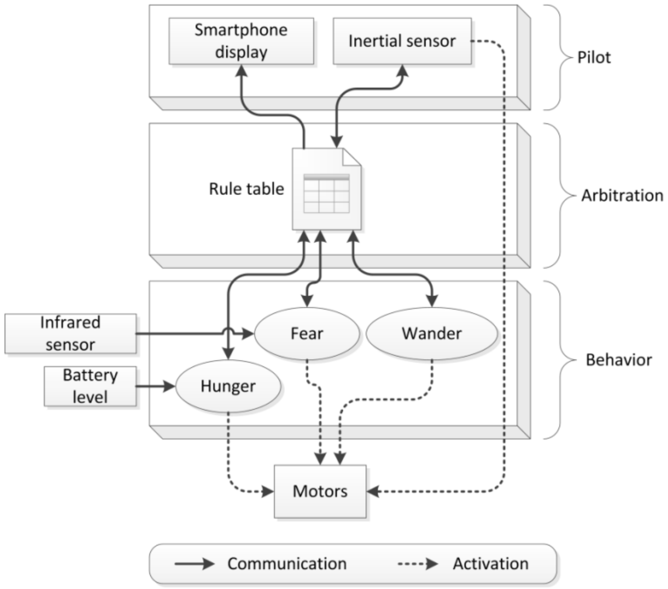

Figure 4 – Control architecture.

VI. Software

Since it uses Android operating system, the embedded control application will be developed in Java programming language with Android SDK (Software Development Kit). To allow the inclusion of new hardware devices, standardized software interfaces were used. In this sense, abstract classes for robots and hybrid sensors were created. The goal is that distinct devices can be used in the same application.

Both the proposed robot and the hybrid sensor can communicate with the computer through a Bluetooth interface. Android communicates with these devices through *android. bluetooth* package, which provides the classes needed to establish connection with Bluetooth devices.

The proposed software architecture is shown in Fig. 5. To execute the initial connection between the hybrid sensor and the smartphone application, it is necessary that a user without severe disabilities interact directly with the smartphone graphical interface, through an ordinary touchscreen interface. Once established the connection, the smartphone is put upon the robot, and the user may begin to control it with the hybrid sensor. The user receives information by observing the interaction between the robot and the physical environment, and also by the faces displayed on the smartphone display (dashed arrows).

The robot application is composed by two main modules: the Graphical User Interface (GUI) and the control architecture. The GUI is used to configure the robot and to show the robot's "faces", while the control architecture activates the robot as described on Section V. Both the GUI and the control architecture depend on the Robot and Hybrid Sensor APIs (Application Programming Interface) to access these devices. Naturally, both APIs are based on the Android Bluetooth stack.

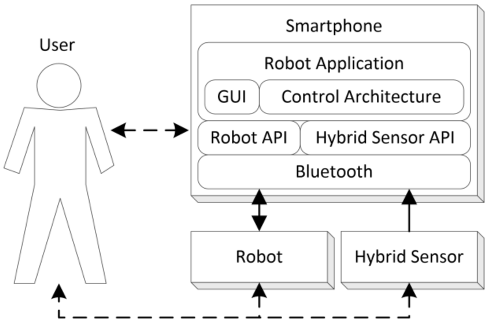

Figure 5 – Software architecture.

VII. Expected Results and Conclusion

The incorporation of behaviors in previous projects' robots has provided an interesting interaction scenario with humans. Unpredictable actions realized by the robot draw children attention and generate the idea of a little pet. A study carried by [16] achieved a similar result with a spherical robot which could navigate on the environment and communicate with children through speech and music. Therefore, we expect 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.

With the improved interaction, we expect children to feel more comfortable with the robot, and thus enjoy the play time. This is particularly important, since this robot will be used to entertain children with severely motor impairments while allowing them to interact with the world through its robotic body.

The chosen behaviors, as reported on Section V, are yet few, and a collection of them require more robust hardware architecture. In this sense, we propose improvements on the hardware architecture with use of embedded smartphones and more robust software architecture. The communication channels between the devices have also been improved, with use of wireless standards.

Basically, the global architecture is divided into three robot levels. The first robot level is comprised by the mechanical artifact and the embedded electronics, and is enough to ensure that the robot can navigate through the environment. The second level is based on the smartphones technology, endowing the robot with behaviors and means of communication with the environment through its sensors. These two levels might work together, side by side, or at the limit distance of the wireless communication channel. The third level consists on a remote computational base, if necessary. This level is responsible of realizing computationally expensive procedures, which includes search for information on the Internet to attend the other parts or even its own evolutional information base. At the same way other levels do, it communicates through wireless channels. It is notable the flexibility comprised to this system, besides its potential capacity of supporting new architectural ideas.

Until now, in previous projects, trials were realized counting only on the first and third levels. Now, we are on the development stage of the second level, which will embed the control architecture, already developed to be controlled remotely. Next, the inclusion of more robust computational base will be considered, to allow users' recognition and to create a database about them. In this way, we hope, in the future, the concretization of an adjustable and more rapidly adaptable to different and more challenging applications on this area.

VIII. Acknowledgement

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