Baby-Goldrake@pediatria.unipd.it: a study about Pediatric Robot (Social Robot + Serious Games)

Abstract
A social robot is an autonomous robot that interacts and communicates with humans or other autonomous physical agents by following social behaviors and rules attached to its role.

The growing diffusion of Social Robotics & Serious Games in the last decade means that they are now as widespread and used as personal computers were 20-25 years ago, and in some contexts (e.g., schools or rehabilitation centers) even more. They are mainly aimed at the entertainment of users, but fun is not their only purpose. They are also used in other, more serious contexts ranging from industry, to education, scientific exploration, health care, emergency management, and many more.

The project aims at taking a step forward in the growing field of development, verification and validation of Pediatric Robots in a Hospital

It is focused on a less explored domain, that of the access to computer by children in a "locked-in" status (condition in which the patient, though being minimally aware, cannot move or communicate verbally due to a complete paralysis of nearly all voluntary muscles in the body). This condition is generally caused by a severe traumatic brain injury (TBI) or produced by medical care through mechanical ventilation (e.g. after poli-trauma, post-neurosurgical conditions, extensive body burns).

Objectives

1. To optimize transmission between the on patient device and the Robot in terms of reliability and security of the wired/optical/wireless channel, throughout the design,

simulation and implementation of signal processing algorithms, security mechanisms and source/channel coding techniques

2. To define a "Phase 0" as emerging from coma/sedation: arousal (eye-open) with minimal and fluctuating awareness. "Phase 0" is an extension of the 3 phases identified in the literature

3. To demonstrate the possibility that children in "Phase 0" (emerging from coma or deep sedation) or "Phase 1" (with stable wakefulness and able to getting attention and responding to yes/no questions) who are incapable of completing any motor function, including speaking, can still drive robots designed to allow a very early and simple augmentative and augmented communication.

4. To evaluate if, in these patients, pediatric robots can accelerate the arising phase and thus favour the work of medical and nursing staff, and thus the quality of care and ultimately a very early rehabilitation;

The research will be taken on in collaboration with Dr. J. Costello, director of the Augmentative Communication Program (ACP) at Boston Children's Hospital (www.childrenshospital.org/acp) and students from Liceo "Enrico Fermi" of Padua (http://www.liceofermipadova.gov.it/)

Definition from http://en.wikipedia.org/wiki/Social_robot#Definition
"A robot is defined in the International Standard of Organization as a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for performance of a variety of tasks. The definition states that a social robot should communicate and interact with humans and embodied agents. These are likely to be cooperative, but the definition is not limited to this situation. Moreover, uncooperative behavior can be considered social in certain situations. The robot could, for example, exhibit competitive behavior within the framework of a game. The robot could also interact with a minimum or no communication. It could, for example, hand tools to an astronaut working on a space station. However, it is likely that some communication will be necessary at some point. Two suggested ultimate requirements for social robots are the Turing Test to determine the robot's communication skills and Isaac Asimov's Three Laws of Robotics for its behavior (The usefulness to apply these requirements in a real-world application, especially in the case of Asimov's laws, still is disputed and maybe not possible at all). However, a consequence of this viewpoint is that a robot that only interacts and communicates with other robots would not be considered to be a social robot: Being social is bound to humans and their society which defines necessary social values, norms and standards. This results in a cultural dependency of social robots since social values, norms and standards differ between cultures.

This brings us directly to the last part of the definition. A social robot must interact within the social rules attached to its role. The role and its rules are defined through society. For example a robotic butler for humans would have to comply with established rules of good service. It should be anticipating, reliable and most of all discreet. A social robot must be aware of this and comply with it. However, social robots that interact with other autonomous robots would also behave and interact according to non-human conventions."

Examples of social robot are:
Nao & Paper by https://www.aldebaran.com/
R25 & R50 by http://www.robokindrobots.com/
Kaspar by University of Hertfordshire.

Innovative features

The most innovative features in this proposal can be summarized as follow:

1. the use of Pediatric Robots in a Hospital to stimulate/allow communication in the early stage of the arousal phase (emerging from coma or exiting deep sedation);
2. the availability of the Pediatric Intensive Care Unit (PICU) at Padua Hospital and other Intensive Care Units to test this new framework
3. the physical and cryptographic securing of the patient - terminal link both for privacy and for accountability purposes
4. the collaboration with The Augmentative Communication Program at Boston Children's Hospital (www.childrenshospital.org/acp) and with Liceo "Enrico Fermi" of Padua - IT.

Foto 1: NAO_BabyGoldrake _BeeBot@aulamagna.liceofermi.padova.it

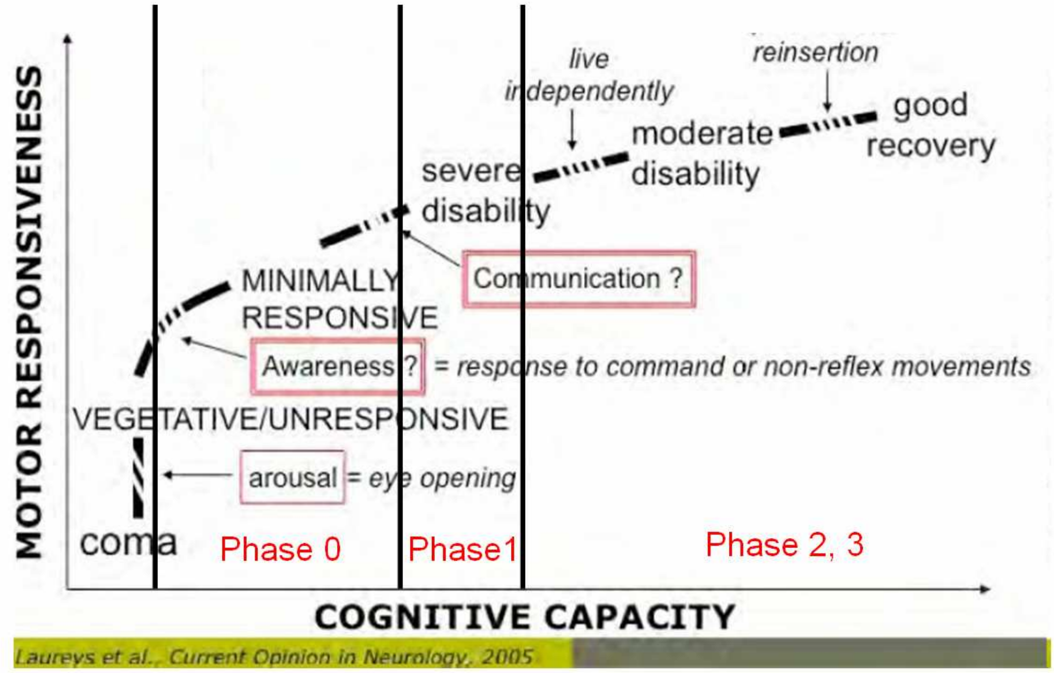
State of the Art

The inability to communicate in PICU is recognized as a terrifying and isolating experience that is related to feelings of panic, insecurity, anger, worry, fear, sleep disturbance, and stress among critically ill patients of any age. Most of these feelings are also experienced by all the people taking care of these patients, such as parents, relatives and medical personnel who want but can't establish effective contacts with the patient [Garrett 2007]. These factors and the impossibility of giving and receiving messages have a clear impact on the recovery or, better, on the rehabilitation phase of the affected patients and thus, possibly, on the speed and quality of the recovery. For all these reasons it becomes imperative to find alternative ways for allowing the affected patients to establish effective communication with the surrounding world [Costello 2012].Modern communication technologies are permeating the attitude of children who, since the beginning of their psycho-social and motor development, are exposed to the application of these technologies. Computerized games are by definition the tools with which children learn, at very early stages in their life, how to deal with the 'language' of communication technologies. Thus AAC systems can be 'hidden' within Pediatric Robots which are very attract children's interests other than find, in them, already expert users. These type of tools are generally called serious games: a game designed for a primary purpose other than pure entertainment [Zulian 2006] and, in this case, it is constructed to allow people 'who can't but have to' to communicate. This tool may also

stimulate the child's willingness to communicate and thus may allow him/her to become the main actor of his/her own rehabilitation process. [Mancin 2012] We propose to call these tools Assistive/Augmentative Serious Games, (ASG) because indeed these are dynamic and flexible tools capable of potentiating and stimulating the emerging abilities of the sick child in a PICU or during the recovering phase.
After years of experience, the staff at the Children's Hospital Boston (CHB), has identified three phases for providing communication access in the PICU.

- **phase 1** **Stable wakefulness**: Getting attention and responding to yes/no questions
- **phase 2** **Increased wakefulness**: Communicating basic information with staff and family
- **phase 3** **Need for broad and diverse communication access:** Communicating about and beyond the hospital environment.

Even if it's very hard to detect and to evaluate in real time the awareness status of an unresponsive patient, a **phase 0** [early emerging from coma or sedation] should be defined as an extension to the 3 phases identified in [Costello 2010].



Security to protect the privacy of medical data
In the processing, transmission and/or storage of medical data, security is typically needed to protect the privacy of patients [Rindfleisch 1997], but also to guarantee the authenticity and integrity of data upon which therapy choices depend that may be critical for the patients life itself.
In particular, for the patient-staff AAC scenario, where the patient may be required to take such critical decisions and prove that he/she fully understands the implications of the possible alternatives, a strong authentication is needed to protect the hospital staff against being charged with dropping critical information or forging patient communication.
However, in the foreseen medical applications of brain computer interface links, such security aspects have so far been overlooked by the research community, while it is considered more of a crucial aspect in military and commercial applications. [Martinovic 2012]

Description of the research
Type of study - Young patients that are temporarily in a “locked-in-status” after a coma/sedation stage in a Pediatric Intensive Care Uniti (PICU) cannot move or communicate verbally due to a complete paralysis of nearly all their voluntary muscles but there is a fluctuating evidence of awareness. It’s rare but possible that the “locked-in-status” lasts more than a few hours maybe even days or Weeks. In these cases the inability to communicate is recognized as a terrifying and isolating experience that is related to feelings of panic, insecurity, anger, worry, fear, and stress among critically ill patients of any age and having a traumatic effect of the subsequent patient's psychological status. It is assumed that the younger the patient, the more severe and potentially irreversible these traumatic effects are.
Most of the feelings perceived by children are also experienced by all the people caring for them: parents, relatives and medical staff who cannot establish effective contacts with them. It can also lead to an increase in sentinel events, medical errors and extended lengths of stay. There is an increasing awareness on this issue within the medical community and thus the development of tools to index the level of consciousness is strongly needed in order to overcome this state of no communication, to improve the quality of care for the patient, and also foster the caretakers' resilience factors and to reduce all the negative effects the child suffers because of this dramatic neurological state. We expect a higher use of the tool, and more positive attitudes and perceptions by parents and staff.

Clinical setting - The study will be conducted in The Pediatric Intensive care unit (PICU) of the Department of Pediatrics at the University Hospital of Padua, Italy.
The PICU is a 10-bed facility serving all the North-East part of the Veneto Region (about 500.000 children less than 18 years of age). The study has been submitted for approval by the Research Ethical Committee of the University Hospital of Padua. The particular children physical condition will guide the development of the ASG Mind Reader 4D to have a very flexible framework in which to integrate alternative input systems as needed. Depending on such physical condition, the input devices can be standard mouse, external dedicated buttons, accelerometer to record even the smaller child movement (a finger for example) or BCI (Brain Computer Inferface) systems, depending of the medical staff indications.

Patient population - All children aged between 3 and 18 years consecutive admitted to the PICU of the Department of Pediatrics at the University Hospital of Padua, Italy in the period of the study either i) suffering of a “locked-in STATUS” or ii) being intubated, partially sedated and incapable of completing any motor function (including speaking). **Based on the PICU data we estimate to involve in the research about 30-40 children every years**. No patient selection by gender, social status, level of education, culture or native language will be used. Patients will be identified by the medical and nursing staff of the PICU and enrolled into the study upon signing of the consensus form by the child's parents or legal guardian. The timing to start using the ASG will be decided by the medical staff, by the researchers and whenever possible after receiving the patient's approval to “play” with the ASG.
Cartakers' population - medical and nursing staff and parents of children will be involved in the research. Based on the PICU data we estimate to involve in the research at least one parent and two professionals for each child. A control group of parents and staff will be selected from other medical units.

Platform - "Mind Reader 4D (MR4D)": an ASG that will be developed by a team of researchers and students of Computer Science. This tool will be a tablet based digital application designed with the same characteristics as other video games in order to facilitates the approach by children. The patient can play with the ASG by interacting with the colored and multimedial screen using whatever motor movement he/she is capable of performing at that specific stage of the recovering. A series of images, sounds and video clips are stored in different levels (files) which are variably accessible according to the child's quality of performance. The ASG contains also real games if the sick child wants only to play. The games can be also constructed to stimulate the personal rehabilitation effort; for example the game can be constructed in a way that it give a prize if the child accomplishes a task which is important for his/her rehabilitation program (for example using one arm other than the other or rising legs or whatever). The ASG can be also used for distant communication with relatives at home, friends, schoolmates in class, having access to e-mail, SMS, FaceBook, Twitter or to mange a little avatar (a walking robot similar to a child with webcam and a synthesized voice). **The ultimate goal of the Baby-Goldrake project is to give sick children the possibility to manage a walking robot from their bed using only their mind.** The MR4D software will integrate signal processing algorithms, security mechanisms, and coding techniques for the reliability, efficiency and security of the brain computer communication. Starting from a precise identification of the reliability/privacy/accountability requirements for our scenario, we envisage an initial phase of modification of existing algorithms and mechanisms to fit the application considered, as well as the design of new algorithms properly suited. The input to the signal processing algorithm will be the raw EEG signal as acquired by the on patient device, whereas the security mechanisms aim at protecting both the raw signal as well as the informative parameters and the semantic interpretation derived from it. In particular we aim at providing strong unconditional security, which can leverage the randomness in the wireless channel, yet it does not require complicated user inputs procedures. In a subsequent phase the techniques previously developed will be implemented and tested on the real platform, for eventual integration into the MR4D.

In brief the project here outlined is designed to produce feasibility data on the use of ASG in children admitted to a pediatric ICU that are suffering from a clinical condition temporarily preventing them for being able to communicate. **The ultimate desired outcome will be the patenting of the entire process and its diffuse use in pediatric as well as in neonatal and in adult ICUs (Neurosurgical and Medical ICU).** Furthermore, it is predicted that these experiences will generate new ideas regarding the use of modern communication technologies in Pediatric Intensive Care Units as well as in other pediatric settings.

To the best of my knowledge this project would represent the first clinical research regarding the use of Pediatric Robots in a Hospital

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