AUGMENTED INTELLIGENCE FOR TEACHING ROBOTS BY IMITATION

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Abstract: *The process of augmenting intelligence in Human Robot Interaction has a complex character and can't be pre-programmed explicitly. Nowadays, teaching robots is a well established concept ranging from demonstration by variants of teleoperation to imitation by external observations. We illustrate an innovative approach for learning intelligence and gestures by imitations of robots by brain augmentation captured by Emotiv brain-listening headset and human poses tracked by Microsoft Kinect motion-sensing device. Thus, robots learn continuously by observations from human brain activities and motions and really become personal. By innovative algorithms, robot operations that satisfy the current physical, cognitive, emotional and social intelligence over time are calculated and transmitted to robot sensors, modules and controllers. The concept of added brain intelligence will also evolve into technology to increase brain capacity and will shape our experience and skills in the future. Summarizing, the paper proposes a new concept for human-robot personal communication by augmenting bio intelligence to robot and vice versa - machine intelligence to human.*

Keywords: TEACHING ROBOTS BY IMITATION, HUMANOID ROBOT NAO, KINECT-ENABLED APPLICATIONS, EMOTIV-ENABLED APPLICATIONS, AUGMENTED BIO INTELLIGENCE, TEACHERS FOR ROBOTS

1. Introduction

Recently, teaching robots has been popular as "programing by demonstration", used when kinematics or dynamic models are difficult to be described and programmed in advanced. The robot behaves like a 'puppet' that operator move and manipulate in real time or record its posture in a timeline-based program in offline mode. We propose another type of teaching - by augmenting brain and gesture intelligence. Robots of the future will coexist and cooperate with humans, therefore they have to achieve physical, cognitive, emotional and social intelligence. The Fourth Revolution began with the rapid development of ICT and AI in particular, allowing a new paradigm for communication: by augmenting bio intelligence to robot and vice versa - machine intelligence to human. An innovative approach for Human-robot interaction (HRI) by brain or motion augmentation that help to personalize the communication with humans are proposed and to some extent illustrated in this paper.

Training robots in complex tasks require humanistic intelligence or human-like movements, impossible to be preprogrammed and calibrated in advance since it is personally specific, difficult to obtain due to the dynamic environment in HRI and continuous need of new repertoire. That imposes human intelligence to be integrated into the digital devices and robots that surround us everywhere. But not digitally by pushing a button, clicking, dragging or speaking, but biologically and continuously through emotions, thoughts or intentions [1]. Thus, digital devices will connect to our physical, emotional and mental state and will be able to meet our needs and at the same time learn from us and really become personal [1]. Thus, we can add intelligence through continuous interaction and feedback between the person and the robot, which will be permanently linked to each other, and the intelligence of the robot will begin to coincide with our own. A symbiosis that puts individual human values at the center of future interfaces to digital devices obeying to the ethical and philosophical considerations. If the robot is connected to human biological essence (the part of us that is most related to our individuality is our brain) on the basis of signals from the brain activity the relevant information can be found about current cognitive and emotional states that play an important role in decision-making, adequate behavior and a healthy lifestyle. Nowadays, teaching robots (the learners) in movements is a well-established concept ranging from demonstration by variants of teleoperation, hand guiding and shadowing to imitation by sensors on a Human (the teacher) or by external observations [2]. Sensors used to record the movements are external to the teacher and may or may not be located on the robot learner. Teaching robots by brain augmentation is a new concept with remarkable development since a decade or two ago recording and decoding brain activity by portable devices was science fiction. Sensors used to record the brain activity are located on the teacher. The brain keeps our cognitive and emotional intelligence, it is a rich source of information and our experience, extremely adaptable and manages our actions [1]. However, what happens in our brains and how to measure it is a great challenge. The brain is hidden and protected, and if invasive approaches and expensive equipment have been used so far, portable, non-invasive and affordable EEG devices (based on encephalography) have emerged with a high-quality output signal. They measure the change in brain pulse voltage by means of sensors on the scalp. "EMOTIV" [3] and "NeuroSky"[4] are pioneers in the field, and the signals received are comparable to those of expensive medical EEGs.

Teaching robots by motion augmentation requires the use of human motion capturing systems for extracting the observed poses. Motion sensing devices and technologies like Microsoft Kinect [5] and Leap Motion [6] allow developers to create innovative applications and solutions that allow users to interact naturally with digital technologies. Leap Motion, the world's most powerful hand tracking, builds a more human reality, really immersive, where Virtual Reality might start with your or robot hands.

The concept of added brain intelligence will also evolve into technology to increase brain capacity and will change our experience and skills in the future by increasing our memory or even communicating with each other by thoughts faster and smarter. Machines learn from information while we learn from experience, so if the information is processed from the robot, we will overcome the massive masses of data avoiding to be overwhelmed by information. Robots will process data and give us the essential and "experience" and this will inevitably affect the health of future generations. Moreover, for people who have suffered from an accident or illness - such brain-machine interfaces will replace lost functionality using emotions, facial expression, and thoughts.

How to teach social or mechanical robots? According to Wikipedia - a social robot is an autonomous robot that interacts and communicates with humans by following social behaviors and rules attached to its role. So, a new profession should be established into near future – *teachers to teach robots*. Those teachers should be aware with social skills and roles. From technical point of view the teachers should be aware with system architecture and system-level view, with the SDK for the technology, how to set up configuration options for the services and how to program the motion-sensing or brain-listening controllers, etc. From developing point of view they should be aware with software algorithms how to process the signals from the brain over time together with machine learning algorithms in order to find relevant information about current emotions, thoughts or intentions that have to be translated into commands for the robots sensors and teletype printing or speech generators. Software algorithms that analyze the Kinect skeleton stream data and identify the 3D positions of body limbs over time with inverse kinematics is an attempt a kinematic model of the robot to be recovered and to be an input for the kinematic modules of the robot.

Thus, we propose a new concept for human-robot personal communication by augmenting bio intelligence to robot and vice versa - machine intelligence to human. The proposed innovative approach for learning intelligence and gestures by imitations of robots by brain augmentation captured by Emotiv brain-listening headset and human poses tracked by Microsoft Kinect motion-sensing device are illustrated and partially implemented in projects METEMSS [7] and Robo-academy [8].

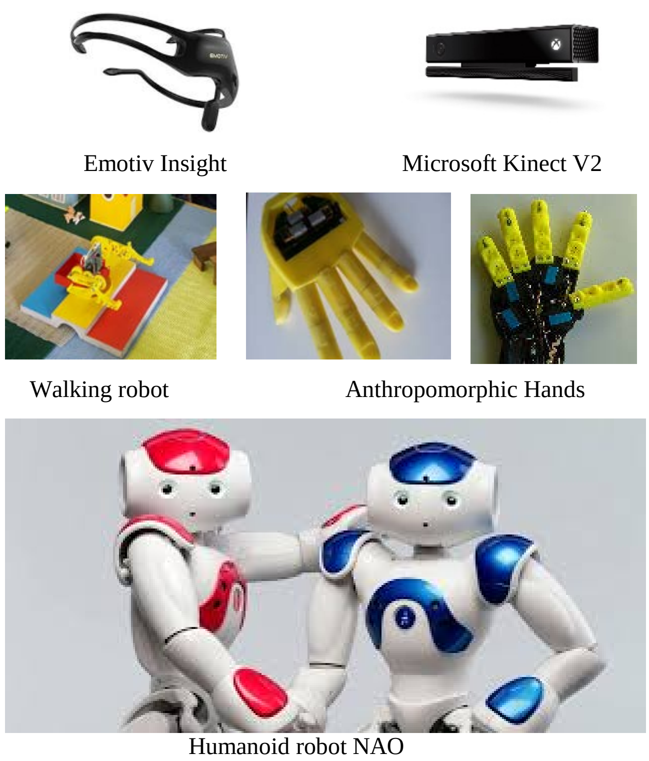

Fig.1 *Assistive technologies in METEMSS [7]*

2. Training robots by Imitation

Training humanoid NAO robot by body parts guiding and integration of the brain-waves and motion sensing systems to humanoid and non-humanoid robots are used as assistive to therapists tools (fig.1.) used for learning by imitation in the context of play for children with special needs in order to engage these children and motivate their social activity, expression of emotions and more body movements [7]. The calibration of used technologies, as well as their integration is for easy to set-up at homes or schools from people without engineer skills.

2.1. Augmented brain Intelligence

In this Section we demonstrate EEG-based system that by a Brain–Computer Interfaces (BCI) translate in real time the electrical activity of the brain to commands in order to control humanoid robot NAO. The research in BCI has started in 1973 [9]. BCIs are systems that can bypass conventional channels of communication (i.e., muscles) to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into commands in real time [10]. With these commands a mobile robot can be controlled or can serve as an assistant of child or a therapist in a joyful skills-learning environment by imitation. Proposed, developed and tested by experiments is an innovative model for development of brain-robot game for learning skills by imitation to help the child to become more emotionally engaged with the social world. The brain activity under consideration is the blinking rate in time that provides a way to monitor the attention and social engagement by measuring blinking on NAO's eyes because children with autism avoid eye contact. The authors in [11] reviews the deployment of EGG based control in assistive robots, especially for those who in need and neurologically disabled. They describe the methods used for (i) EEG data acquisition and signal preprocessing, (ii) feature extraction and (iii) signal classification methods.

In the proposed system we use EMOTIV Insight Brain Activity Tracker with 5 electrodes and 2 referenced to record EEG signal. It is a 5 channel, wireless headset that records and translates human brainwaves into meaningful data you can understand. In the current project we use 1 of them on the forehead to construct a Brain-Computer Interface (BCI) to control the NAO eyes led sensors through wireless interface. First, EEG signals were filtered in order to extract the different brain rhythms (δ, θ, α, β), so that the different frequency bands were individually analyzed, as well as combined together. The existing EEG based biometric systems are classified to the employed acquisition protocols in terms of cognitive task, the number of electrodes and their spatial configuration, the feature extraction algorithms, the classification algorithms and their effectiveness in clustering the observations [11]. For example, Fig. 2. shows an examples of Delta, Theta, Alpha, Beta, and Gamma waves acquired through the channel O2 using a "rest state with closed eyes" protocol.

We considered different channel configurations to obtain the most reliable acquisition protocol using the AF4channel. Then, we extract the features for eye-blinking from EEG signals as the ratio between the power of Theta and Alpha rhythms. We map the changing of this peak to parameters of eye-LEDs that mimic NAO blinking in order to control NAO's eye-LEDs in ALLeds module on the robot side.

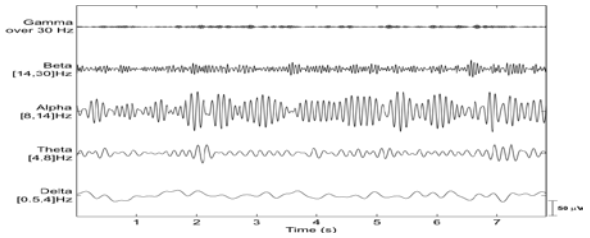

Fig. 2. *Taken from [11] - Delta, Theta, Alpha, Beta, and Gamma waves acquired through the channel O2 using a "rest state with closed eyes" protocol*

The proposed EMOTIV-NAO framework, combining the BCI with the APIs of the NAO robot, is enough general and could be used for different cognitive tasks or other EEG-based controlled mobile robots.

2.2. Training robots in human-like movements

Human-robot interaction by gestures personalizes the communication with humans in various contexts, from daily life to special educational needs. Human-like movements in gestures can't be pre-programmed explicitly since the localization and motion planning of humanoid robots relies on dynamic/kinematic models, which are not always available or difficult to obtain due to the dynamic environment in HRI. Since, the marker based motion captured systems for extracting 3D poses over time are expensive and require careful calibration, a lot of work has been studied for imitation by external observations for extracting 3D poses from an image sequence. Sensors used to record the movements are external to the teacher and may or may not be located on the robot learner. We propose in [12, 13, 14] different innovative approaches for teaching robots to imitate gestures. In [12] we integrate Kinect motion-sensing device and controller with direct feedback from an originally developed angular displacement sensors mounted in an artificial anthropomorphic robot hand. The robot learns by external observations of the 3D teacher poses captured by Kinect. We analyze the Kinect skeleton stream data and identify the 3D positions of upper body limbs over time. Inverse kinematics algorithm for calculating the corresponding joint angles for each pose and decomposition into a per-frame algorithm and a method for optimal control of joint motors by position in a lack of a dynamic model is found. More details for the proposed, developed and tested by experiments models for teaching robots to imitate gestures can be found in [12] and [13], where two different prototype of artificial hands were designed and tested. Processing Kinect body data to solve Inverse Kinematics task for teleoperation of humanoid robot NAO is presented in more details in [14]. We analyze the Kinect depth and body stream data and identify the 3D positions of upper body limbs over time. The important joints for motion retargeting of upper limbs are left and right shoulder, elbow, wrist and hand (Fig.3.).

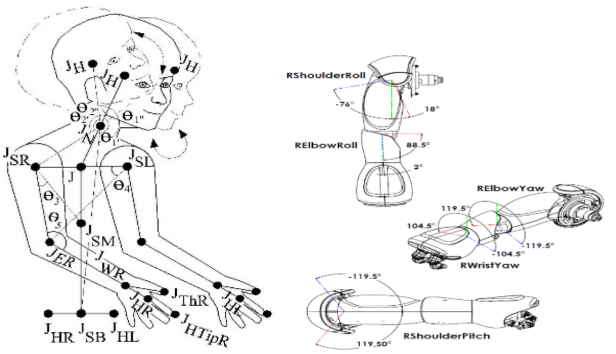

Fig.3. *Important joints for motion retargeting of upper limbs to 3D model of the Nao right upper limb*

3. Training robots by body parts guiding and shadowing labelled and tailored to bio signals

This section illustrates how to teach by animation programmable robots in complex movements by body part guiding and recording in timeline mode. The illustration of steps are for NAO robot with Choregraphe [15] - a multi-platform desktop application, allowing teachers to create animations, behaviors and dialogs, test them on a simulated robot, or directly on a real one, monitor and control NAO and enrich Choregraphe behaviors with own Python code.

In Choregraphe you can use an 'Animation Mode' for Training robots by body parts guiding and shadowing. In the 'Animation Mode' you create movements easily, in conjunction with the Timeline Editor. In this mode, *the robot behaves like a puppet* that you can manipulate, letting you record its posture in a Timeline. In this mode, tactile commands help you manipulate the robot. You can use tactile commands to manage the stiffness. A visual feedback let you know which limb is currently stiffened or not. Yellow means that the Stiffness is 'On'. Green means that the Stiffness is 'Off'. Use Stiffness-control tactile commands to manipulate its limbs one by one in order to make the robot take the posture you want to store. When you change the real NAO position, you can see that the virtual 3D NAO changes position too. To move joints of a simulated robot, using the Limb properties that allow you to check and modify the joint values (and then move the limbs) using the Limb properties. This panel enables you to modify the joint values of each limb and allows you to adjust the joint value. You can move it, as well as enter a value in the associated text box. The robot tries to reach the command value with its joint as soon as possible. At each steps you have to save the defined values in the currently opened Timeline box [15].

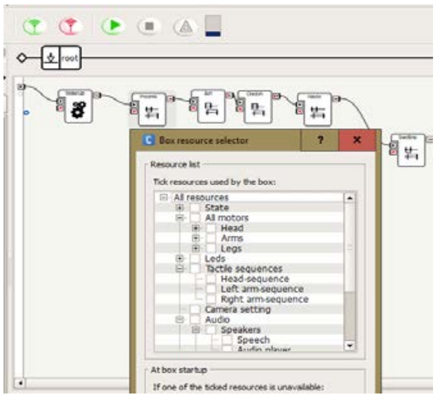

Fig. 4. *Resource list used in the Timeline box*

We propose during the animation to decompose the desired movement in order to use switch case over the single motions. For instance, you teach your robot in complex movements, however you would like to use script to switch them depending on daytime, accessibility, task to do, obstacles at home/office, brain activity, emotions and intensions. Thus, you need to run a Python script to access a Timeline object. In Python *load and unload* events methods automatically are called when the box is loaded or unloaded. Resource list used in the Choregraphe Timeline box (as shown in Fig.4) in Python method *"onResource"* is called when the resources of the box are set to Callback on demand and the resources are asked by another box. You need to define resource functions for it to be called.

The choreographies tailored to songs in the project METEMSS [7] are an example how to adapt to the *style of dance* that fits the target groups.

4. Training teachers to teach robots

The proposed from us new paradigm for augmenting bio intelligence to robot and machine intelligence to human requires a change in the way how robots to be trained. This imposes a new profession "teachers for robots" to be appeared in a near future. It is most natural for our community programmers to be assigns to do this by going through additional training. What additional skills are required and how to teach social or mechanical robots? Robot communicates with humans obeying to rules attached to its role. So, teachers should be aware with skills and roles. Since the robots will work at the same workplace and coexist with people and other robots, they need to socialize. Robots must comply with ethical and legal norms. Asimov's three laws for the behavior of robots are a good basis for the development of a modern legal normative base. They have to be "implemented" in the teaching process but not only. The perception of "good and bad" for people and robots is different. Additional training of teachers for generic guidelines for robot behavior is imposed by the greater ubiquity of robots.

Another point of view could be seen in [16], where authors make a concrete, operational proposal as to how the information-theoretic concept of empowerment can be used as a generic heuristic to quantify concepts, such as self- preservation, protection of the human partner, and responding to human actions. They focus less on how a robot can technically achieve a predefined goal and more on what a robot should do in the first place. They are interested how a heuristic should look like, which motivates the robot's behavior in interaction with humans. They present proof-of-principle scenarios demonstrating how empowerment interpreted in light of these perspectives allows one to specify core concepts with a similar aim as Asimov's Three Laws of Robotics in an operational way. Significantly, this way does not depend on having to establish an explicit verbalized understanding of human language and conventions in the robots [16].

Robot teachers must have sufficient knowledge of the technical specifications and robot services. They need to apply appropriate syllabus and teaching through appropriate programming tools. Robot training methods today are at an early stage of development. One is the teaching by imitation, which is specifically and partly offered in the present work. It is illustrated in terms of imitation of some human movements that are reproduced by a particular robot. This approach will continue with respect to all movements and imitation of human behavior in different conditions.

Where the training should take place? Probably in specialized services and / or in "robot schools". The future development of robotics will impose not only new rules and legislations to be created but also engineering knowledge, practical manuals and training syllabuses.

5. Conclusions

The main contribution in the proposed paper is the innovative model how to augment to robots physical, cognitive, emotional and social intelligence and vice versa experience and memory to humans. We describe and demonstrate the potential of the EMOTIV-ROBOT and KINECT-ROBOT frameworks for providing a natural interface to teach robots by imitation to perform mechanical and social tasks that are impossible to be preprogramed and calibrated in advance. At the same time, the proposed from us new paradigm for augmenting bio intelligence to robot and machine intelligence to human requires transformations in the way how robots to be trained. The learning of people how to teach robots and appearance of new profession “teachers for robots" is inevitable. These teachers should take additional training in knowledge and heuristics concerning how to motivate the robot’s social behavior in interaction with humans and updating the Asimov’s Three Laws of Robotics.

Acknowledgments

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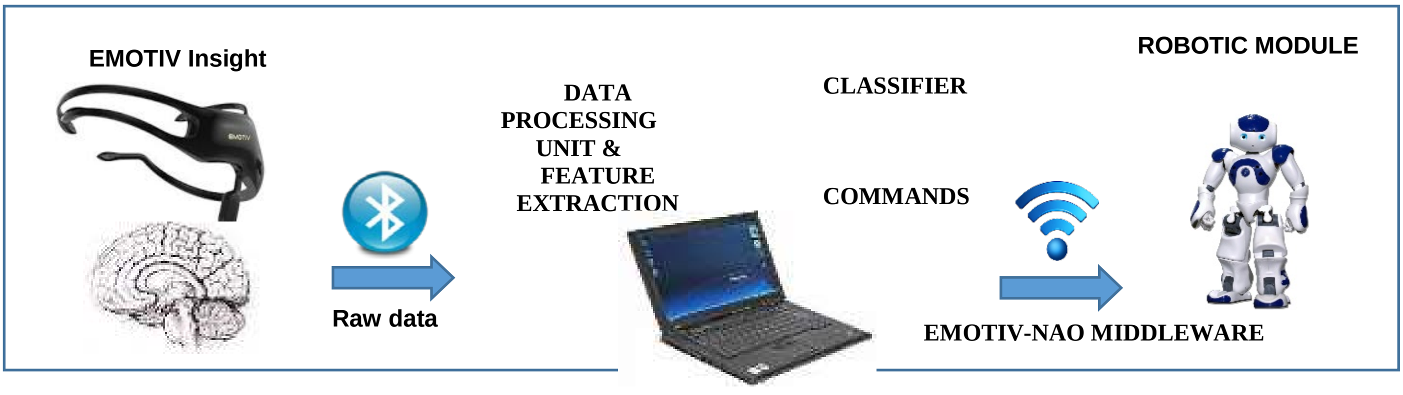

Fig. 3. EMOTIV-NAO wireless framework for developing an EEG based brain-robot interface