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Editorial

At the beginning of the third millennium, it is unquestionable that robotics and neuroscience are complementary disciplines. Their complementary nature is revealed by the bulk of research in progress to emulate functional properties of the brain, as learning and memory, in robotics devices. Nevertheless, brain–computer interfaces are ready to help people with degenerative or post-traumatic severe motor impairment. Motor control itself represents a suitable ground for a strict interaction between robotics and neuroscience. Synergies between these two disciplines are both technological and methodological. For instance, robotic technologies, such as tactile force sensors and haptic interfaces, are used to quantify forces produced in a human grasp. As far as methodology is concerned, robotics can provide mathematical models to help the investigation of the working brain. The control of anthropomorphic robotic arms or hands is an important subject in the robotic research. These studies basically focus on the main physical phenomena involved in the grasp such as friction and gravity and can therefore be used to interpret some rules governing human motor control during actions.

Another field in which robotics and neuroscience can mutually interact is the physiological control of specific human senses or motor actions. We are referring to what we call designing sensory mismatches and illusions: by immersing the human subject in a virtual reality environment, and by means of techniques exploring the electrical or metabolic cerebral activity, scientists can monitor what happens in a “surprised” healthy brain during an artificial change of the expected sensory feedback. Likely, this information can be used to better understand what happens in a lesioned brain. We believe that designing illusions and sensory mismatches are one of the more promising research areas for studying the neurophysiological background of adapting brain changes.

The aim of this special issue is to make an attempt to delineate the state of the art of several outstanding synergies between robotics and neuroscience and to individuate possible common grounds of future developments.

The current special issue consists of eleven papers. Each paper has been evaluated by distinguished colleagues belonging both to robotics/engineering and neuroscience communities and has been judged not only on the basis of the absolute scientific merit of the work, but also in terms of the degree of interaction between the two disciplines and the potential application of the results in the near future. At the end of this reviewing process, among a greater number of submitted manuscripts we selected the following ones that we are going to briefly present, grouped into three main topics:

(1) Using robotic models to understand human behaviour and design illusions.

The first four papers of the special issue deal with studies on robotic modelling and control, which have been used to explain how the brain works in some special sensorimotor task execution. A special emphasis on tactile illusions has been placed in two of them.

The paper “Does the brain make waves to improve stability” by Joseph McIntyre and Jean-Jacques E. Slotine addresses an interesting comparison on motion control from a distance, in humans and robotic systems. In particular, they propose to use the concept of wave variables in control engineering to interpret how sensory feedback delays are dealt with by the sensory–motor system in humans.

In “Contact forces evoked by transcranial magnetic stimulation of the motor cortex in a multi-finger grasp” by Gabriel Baud-Bovy, Domenico Prattichizzo and Simone Rossi, a new haptic device (i.e., the Tripod Grasp Analyzer) measuring simultaneously the finger forces into a grasp has been coupled with transcranial magnetic stimulation of the motor cortex, a technique to stimulate the brain noninvasively. This allows to measure, besides conventional neurophysiological parameters reflecting the cortico-muscular drive, the motor evoked forces (MEFs) within a multi-point grasp, disclosing intriguing relationships between the grip force (which measures the overall force involved in the grasp), the net force (which measures the net effect of all contact forces exerted by fingers on the object) and the characteristic of the TMS pulse on the motor cortex.

The paper “Tactile flow explains haptic counterparts of common visual illusions” by Antonio Bicchi, Enzo P. Scilingo, Emiliano Ricciardi and Pietro Pietrini, suggests that the optical flow, a well-known concept in computer vision and robotics, when used to estimate the time before the contact with an approaching object, can inspire computational models to grab the fundamental psychophysical aspects in perception of dynamic stimuli in the visual and tactile sensory modalities. This paper also investigates illusions, and in particular similarities between visual and new tactile illusions, including the well-known “barber-pole” effect.

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The main contribution of the fourth paper of the special issue, “A brief taxonomy of tactile illusions and demonstrations that can be done in a hardware store” by Vincent Hayward is a deep investigation and taxonomy of tactile illusions. The Author perspicuously presents twenty types of tactile illusions and discusses the ease with which they can be demonstrated and whether they have clear visual analogues.

(2) Multimodal integration, imitation and mirror neurons.

Multi-modal interaction and sensori–motor integration with possible interpretation trough mirror neurons have been studied in the second group of papers.

The paper “Tri-modal integration of visual, tactile and auditory signals for the perception of sequences of events” by Jean-Pierre Bresciani, Franziska Dammeier and Marc O. Ernst investigates the interactions between visual, tactile and auditory sensory signals for the perception of sequences of events and sketches interesting conclusions on single contributions and reliabilities of modalities and on the role of the executed tasks.

The second paper “Backward and common-onset masking of vibrotactile stimuli” by Mario Enriquez and Karon E. MacLean, investigates two mechanisms for temporal masking of vibrotactile stimuli. Mechanisms that can explain the experimental results are proposed, with consequent implications for the design of user interfaces that rely on tactile transmission of information.

The seventh paper, entitled “Temporal prediction of touch instant during observation of human and robot grasping” by Laila Craighero, Francesco Bonetti, Luca Massarenti, Rosario Canto, Maddalena Fabbri Destro and Luciano Fadiga investigates the ability to predict the instant at which a grasping hand touches an object. The hypothesis here is that, because of the activation of the mirror–neuron system, the same predictive process necessary for action execution should be active during observation. In particular, interpretation of experimental results provides indication of the synergic contribution of both object-related (canonical) and action-related (mirror) neurons during observation of actions directed towards graspable objects.

The eighth paper, “From Self-Observation to Imitation: Visuomotor Association on a Robotic Hand” by Thierry Chaminade, Erhan Ozto, Gordon Cheng and Mitsuo Kawato studies the hypothesis that imitation is not innate, but rather that basic forms of imitation could emerge as a result of self-observation. Their suggestion is that such a complex behaviour as imitation could be, at the neuronal level, founded on basic mechanisms of associative learning. This notion is supported by a recent proposal on the developmental origin of mirror neurons system. The approach has been shown to be suitable for the development of realistic cognitive architectures for humanoid robots as well as to shed new light on the cognitive processes at play in early human cognitive development.

(3) Technology and rehabilitation.

In “Bio-inspired sensorization of a biomechatronic robot hand for the grasp-and-lift task” by Benoni B. Edin, L. Ascari, Lucia Beccai, Stefano Roccella, John-John Cabibihan and Maria C. Carrozza, authors observe that humans rely on detecting discrete mechanical events that occur when grasping, lifting and replacing an object, i.e., during a prototypical manipulation task. Such events represent transitions between phases of the evolving manipulation task such as object contact, lift-off, etc., and appear to provide critical information required for the sequential control of the task as well as for corrections and parameterization of the task. Authors developed a sensorized biomechatronic anthropomorphic hand to detect mechanical transients and test their observations. Potential use of these technologies in prosthetic devices is discussed.

In the paper “Non-Invasive Brain–Computer Interface system: towards its application as assistive technology” by Febo Cincotti, Donatella Mattia, Fabio Aloise, Simona Bufalari, Gerwin Schalk, Giuseppe Oriolo, Andrea Cherubini, Maria Grazia Marciani and Fabio Babiloni, authors show how the quality of life of people suffering from severe motor disabilities can benefit from the use of current assistive technology capable of ameliorating communication, house-environment management and mobility, according to the user’s residual motor abilities.

Finally, the paper “Visual Feedback Distortion in a Robotic Environment for Hand Rehabilitation” by Bambi R. Brewer, Roberta L. Klatzky and Yoky Matsuoka. In this paper authors focus on individuals who demonstrate learned nonuse, a tendency to use affected limbs below the level of the individual’s true capability and propose a paradigm applying visual feedback distortion to the rehabilitation of individuals with chronic stroke and traumatic brain injury. The aim is that visual feedback distortion may help a patient move beyond his or her self-assessed best performance, improving the outcome of robotic rehabilitation.

We want to acknowledge all the Authors and Reviewers that contributed with their work to make this ambitious project an important picture of the more advanced research in robotics and neuroscience. A special thanks goes to all the colleagues and friends that encouraged us to realize this project, and in particular to the Associate Editor Pietro Pietrini who launched the idea of this editorial enterprise.

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