Dexterous Transradial Osseointegrated Prosthesis with neural control and sensory feedback

Reporting

Project Information

DeTOP
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Periodic Reporting for period 3 - DeTOP (Dexterous Transradial Osseointegrated Prosthesis with neural control and sensory feedback)

Reporting period: 2018-09-01 to 2021-08-31
The DeTOP project targets people with reduced or absent hand sensorimotor capabilities, due to an amputation. The latter is known to cause severe physical and psychosocial dysfunction. Besides the obvious inability to grasp and manipulate objects, as well as to sense the environment through the sense of touch and proprioception, the hand may no longer be used for gestures that normally support speech and emotional expressions. Additionally, the physical differences compared to other people can result in severe psychological problems. DeTOP aims to develop the next-generation transradial prosthesis by clinically implementing robotic, sensing and long-term interfacing technologies.

Core of the system is an osseointegrated human-machine gateway (OHMG), able to create bidirectional links between a human and a robotic prosthesis. The OHMG is an enhancement of the OPRA Implant System (by Integrum AB, Sweden). The latter consists of two main components, the fixture and the abutment, mechanically secured by a screw so that the loads are directly transferred between the prosthesis and the skeleton. The OHMG also allows for bidirectional electrical communication, between the prosthesis and electrodes in the body (Fig. 1). Hence this system can provide direct electrical access with peripheral neuromuscular structures of the body, using suitable electrodes. For example, myoelectric signals recorded using epymisial electrodes can be collected and used for controlling a prosthesis; vice-versa cuff electrodes can convey sensory feedback to the brain, using an external stimulator connected to tactile sensors in the hand. Because of these unique features, today the OHMG is probably the most advanced technique for bidirectional neuromuscular interfacing, suited for the upper limb amputees, which was proven functional in the long term. Notably, the first recipient of the OHMG system is a patient with a trans-humeral amputation which was implanted in January 2013 – since then is using it. This successful case paved the way for DeTOP and now opens the door for the study and implementation of more natural and complete prostheses. The goal of DeTOP is to push the boundaries of this technology -made in Europe- and to make it clinically available to the largest population of upper limb amputees, namely transradial amputees. This objective will be targeted by developing a novel prosthetic hand with improved functionality, smart mechatronic devices/features for safe implantable technology, and by studying and assessing paradigms for natural control (action) and sensory feedback (perception) of the prosthesis through the OHMG.

DeTOP will not only develop ready-to-use human-machine-interfaces and dexterous prostheses for the disabled; the interfaces and systems developed within the project will be chronically implanted in selected patients which will take the systems at home.

The overall concept underpinning the project is shown in Fig. 2. The 3 scenarios share the same modular design and are composed of six main blocks in order to handle parallel streams of efferent (control signals – dependent on user’s intent) and afferent (sensory feedback signals – based on artificial senses in the prostheses) information. Starting from the human body the six blocks are: (1) the implanted electrodes, (2) the OHMG-TR, (3) the recording/stimulation electronics, (4) the processing and communication nodes, (5) the mechatronic coupler and (6) the hand/wrist prosthesis with proprioception and tactile sensors.
The project has contributed to set up the following activities:
• Design and development of a new Sensorized Hand Prosthesis (SHP) with embedded force sensors;
• Design and development of new wrist prototypes;
• Development and test of a new attachment device that preserves natural forearm rotation while providing a connection that is mechanically and electrically satisfactory;
• Design, development of the OHMG-TR and implantation in two participants with below elbow amputation;
• Collect databases of iEMG, HD-sEMG and eEMG signals;
• Development of different machine learning algorithms that allow dexterous control of the prosthetic devices;
• Advance the understanding of human sense of touch;
• Development of a portable neural stimulator that can be integrated in the hand prosthesis;
• Design and development of the Miniature Processing and Communication node;
• Definition, design and implementation of a high throughput time-constrained RF protocol;
• Integration and home use of the DeTOP osseointegrated prosthesis with neuromuscular interface, with one participant;
• Dissemination of the project on several national and international media channels and conferences;
• Identification of foreseen exploitable outcomes.

In support to the previous activities we:
• published 35 scientific papers on international journals;
• gave 39 presentations at international conferences;
• gave 15 invited presentations.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

The results from this project would impact not only for offering a new solution to people suffering from limb amputation, but also to those having disabling motor deficits due to other neurological diseases (stroke, brain and spinal cord trauma, brachial or lumbosacral plexus and peripheral nerve injuries etc.) which presently affect millions of patients in European countries. More in particular, the objectives of the project are very important:
- for social and clinical implications because it is calculated that about 2000 hand amputations occur every year in Europe.
- for the biomedical industry because the final results could be exploited by new or existing companies manufacturing limb prostheses, implantable technologies, biomedical instruments and in general assistive technologies.
- for neuroscience because by increasing the basic understanding on the way the nervous system dispatches the commands to control the hand to grasp objects, and on the way the cutaneous sensors convey sensory information to the brain, will provide a unique opportunity to learn about the sensorimotor control of limb function.
- for cognitive neuroscience because the understanding on the way our brain internalize new afferent
channels, and perceives external devices as “own” is important for all (external) prostheses.
- for upper limb occupational therapy, because the assessment of the prosthesis by patients, will help understanding the effective power of traditional tests, and lead towards the development of new ones.
- for consumer electronics, because the network of processing/communication nodes finds a broad range of application scenarios into mainstream markets like healthcare, consumer electronics, domotics, computer gaming, etc.
- for surgery procedures, because the bone-anchoring (osseointegration) implants, surgical methods and procedures will benefit from the lessons learned for implanting the novel OHMG-TR.

Fig. 1 DeTOP overall concept

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