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Biomedical Engineering – The Strong Link between Medicine and Engineering

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Biomedical Engineering aims at merging engineering principles and concepts with medicine requirements in order to produce advanced results in healthcare. Over the last 50 years it has had a growing impact on society thanks to the advances in technological fields and to the widespread adoption of interdisciplinary and patient-centered approaches.

Many research areas integrate the knowledge of engineering and medicine, such as: robotics, signal processing, bioinformatics, tissue engineering, biosensors, biomaterials, biomechanics, image processing, imaging, neural and rehabilitation engineering, assistive technologies, telemedicine, artificial organs, prosthetics.

The interdisciplinarity of biomedical engineering research is guaranteed by multidisciplinary teams where engineers work side by side with clinicians. The medical knowledge of the clinical challenges and of the medical and patient needs is the fundamental inspiration for the engineering part of the teams. Conversely, the engineering knowledge of hardware, software and methods provides the medical part with technologies for prevention, diagnosis and treatment of diseases, so as for patient care and rehabilitation. This closed loop is the main cause of the fundamental advances obtained over the years in the field of biomedical engineering.

As outlined by Shu Chien et al. in [1], “Engineering and technological advances have played a major role in medical discoveries and their clinical translation”. Cardiac pacemakers, heart valve prostheses, ultrasounds, artificial body part replacements, biosensors, are just some examples of the strong cooperation between engineering and medicine in prolonging lives of patients or improving their quality of life.

The growing impact biomedical solutions are having on the society is also due to the continuous increase of the average population age, which is leading to a consequent increase of health-care needs and of the associated demands and costs. The World Health Organization estimated that in 2050, the number of people who will need a support system will grow to almost double [2].

Specific and long-term treatments for chronic diseases in the ageing population emphasize the central role of the patient in the technology development.

For instance, scientific research in assistive technologies tries to integrate user residual capabilities with the technology for letting people who largely depends on caregivers for daily living activities, including leisure and communication, to actively participate to social life. The user residual capabilities are emphasized and adopted by the technology for letting the user to autonomously execute the most common activities. The assistive devices are realized in such a way to be adaptable to the user particular needs and residual capabilities [3], with the aim of maximizing the system usability and its acceptance by the users. In the development of assistive devices it is fundamental to guarantee the centrality of the patient, which should be considered in his/her entirety, paying attention to cultural, environmental, relational aspects and to his/her lifestyle. It is necessary to know not only which pathology the user is affected by, but also which type of patient is affected by a particular pathology in order to meet the real needs and satisfy the actual demands of the users. In general, patients should feel supported in every step of their fight against the disease.

In the field of limb prosthetics, despite the advancement in technology developments and surgery in the last 70 years, there are still significant limitations which imply a high rate of abandonment of the prostheses (20-30%) by the users [4]. In particular, the lack of intuitive and reliable interfacing systems with the prosthesis, the absence of sensory feedback, the inability to perform actions with a high coordination between prosthesis degrees of freedom and with less visual attention, entail that these systems do not completely accomplish the user needs. In order to overcome these limitations, research is focusing on including the patient in the prosthesis control loop [5]. Therefore, this is characterized by a bidirectional communication between the user (especially through the Peripheral Nervous System, PNS) and the prosthetic system by means of modules such as (i) an interfacing system able to record and stimulate and also responsible of the communication with the PNS by efferent and afferent channels. Studies demonstrated the feasibility of using implantable peripheral interfaces for naturally controlling the prosthesis and feed back to the patient tactile information [6,7], (ii) a control system guiding prosthesis actuators on the basis of proprioceptive and tactile/force information. User intention is decoded by signals recorded on the efferent channel via different types of interfaces and it is used to generate control commands; (iii) a sensory system on board of the prosthesis for feeding back to the user tactile information about the hand-object interaction, via the peripheral interfaces on the afferent channel, and to the control system, for regulating grasping forces or handling slippage events [8], decreasing the cognitive load for the patient.

Such a system would allow satisfying user requirements by enabling:

(i) The management of grasping and manipulation forces, (ii) the management of more degrees of freedom of the prosthetic limb, increasing its dexterity, (iii) the reduction of the visual attention the user has to devote to grasping by giving greater importance to sensory feedback, (iv) the increase of the number of feasible grasping configuration and the implementation of simple manipulation actions.

Of course, a great amount of research is still needed to understand the human being and provide materials and methods for meeting clinical and patient needs. Over the years, the European Union and the World Health Organization launched several calls and funded several projects on this issue in the attempt to have more affordable health technologies.

In the future, one can expect biomedical research will focus on (i) implantable devices, for substituting or controlling the functionality of compromised organs; (ii) design and use of nanoparticles/nanosystems for tumor treatments and diagnostics; (iii) regenerative medicine (and therefore biomaterials, biomechanics, biotransport phenomena and tissue engineering) to repair or replace damaged organs; (iv) new methodologies for noninvasive and not expensive image acquisition and processing for diagnosis and image guided surgery; (v) neural interfaces able to harvest in a safe and robust way a huge amount of independent control signals from the body for controlling prosthetic and assistive devices; (vi) assistive devices for monitoring patient health status and increasing patient autonomy and quality of life.

One of the main issues in biomedical research is to make the obtained results available to everybody. This is especially important for low- and middle-income countries, where people cannot afford even simple technologies. It is essential to work towards the *democratization* of the health care providing high-quality and cost-effective care.

The even stronger cooperation between engineering and medicine will certainly succeed in getting an accurate, innovative and higher quality health care at reduced costs, transforming some of today's dreams into reality.

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