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BIODESIGN: NEW INTERDISCIPLINARY PROJECT APPROACH

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ABSTRACT

What is biodesign? How does a Biodesigner manage a project dealing with bio-devices? How important could be an integrated approach regarding artificial devices for human body? Designing bio-device means changing to an interdisciplinary approach to find answers to severe issues. It becomes more and more important when the research area involves the design and use of new technologies, like MEMS and bioMEMS, for innovative application in bio-robotic devices. Moreover, nanotechnology is taking its first steps towards revolutions in human-artificial interface.

The topic of this paper is the new role that the bio-designer must have in bio-product projects. The crossover from design to bio-design is necessary because in present reality, the complex field of health care devices needs to have a different approach, that is crossing the interdisciplinary barriers.

In the general introduction, theoretical basis are laid in order to show the importance of designer cooperation in micro-technologies study and in their innovative applications. Designer can make easier the cooperation amongst experts, co-ordinating design process among several research fields and skills. In this first part problems, complexity, application fields and design methodologies connected to bio-robotic devices are highlighted. Corresponding courses in education of experts in Biodesign is presented and discussed.

Keywords: Biodesign, microtechnologies, methodologies, interdisciplinary education

1 INTRODUCTION

Bio-robotic systems could be defined as advanced integrated elements, made of mechanical components, sensors, actuators, control and man/machine interface. More precisely, Biorobotics is denoted by pervasive presence of natural life, from bio-inspired AI techniques to any machine organic-artificial coupling. In the present context, the "bio" prefix focuses on the centrality of human body in the design process of any artificial device used for (or in) the body itself [3]. Nevertheless, since the last few years, the natural-artificial interdependence got benefit from technological impulse towards miniaturization, decisive for overcome the "micro" barriers and to enter the "nano" field, enhancing the potential impact of the so-called *smart technologies*. The convergence of micro and nano-technologies (MNT) with biology assures exceptional progresses and potential massive cost reduction for medical and health-care applications [1]. The expected solutions will provide the chance to realize unique systems for the future generation of medico-diagnostic Point-of-Care instrumentation (POC) [5]. Such solutions represent an example of the specific integration of knowledge, processes and technologies in a cross boundary trend among the MNT's disciplines and medical world. In addition, from the final user point of view, innovation increases demand for functionality, performances, efficiency in information exchange and more valuable utilities addressing and personal wellbeing problems.

In this scenario, a powerful integration between advanced technology at microscale and applied research could reach effective results in human body applications. If artificial bio-devices are likely to be one of the most expected technological synthesis for health applications, a requested task for *Biodesign* is to set up a proper approach for industrial design in the described technological synthesis.

In the last decades, the interest in researches for solutions specifically directed to the human-being raised a number of *bio*-disciplines (from greek prefix for *life*) and involves various thematic areas like architecture, engineering, medicine, physics and chemistry. These sectors could be firstly considered as a kind of specialization of already existing and well-established disciplines. So it could be said that every discipline that has reached a remarkable development is likely to need a further degree of specialization or, better, to concentrate its own efforts on the in-depth study of the human-being addressing what could be called the "bio" problem. Also the industrial design, as well as for other disciplines, has been accomplishing a real renewal in core priority assumption towards man and his body. Starting from this scenario, a new specialization of industrial design is required not only for supporting biomedical solutions but also for being strongly oriented to medical design in every step.

Hence, Biodesign is an applied research discipline devoted to the integration of new technologies in every device for human body considering it as a psycho-biological *unicum.* (see more detailed discussion in [8]). The vocational attitude for different skills in technology integration leads the Biodesign into multidisciplinary environment whenever solving the complexity is required in projects due to development of top notch technology products (see §2). More precisely, a synergic cooperation of different skills is needed along the entire design process and not only for enclosed tasks. Therefore an appropriate educational system is useful for developing an interdisciplinary experience in order to prepare Biodesigners in mastering multidisciplinary knowledge and cooperation methods. In §3 an example of teaching course for Biodesigners is outlined along with experiences for trying out a real cooperation in lab projects.

2 BIODESIGN: TO GET OVER THE DISCIPLINARY BARRIERS

As previously outlined, Biodesign proposes the main research and development contribution in creation of artificial devices and in the integration of new and more appropriate technologies in biomedical and bio-robotics areas, closely related with man in body and personality. For these reasons, a specific product designer should be involved in the entire process of development of bio-devices, playing a remarkable role within the project team. As a specialist, a biodesigner could improve the usage and acceptance aspects of bio-devices. For instance, every device for health care should be, at least ideally, tailored for and interfaced with the user. Ergonomics and quality in utilization become therefore very significant elements in biodesigner's project tasks. Patients or users often reject devices they feel extraneous, even if such devices could improve their quality of life. This lack in quality in projects is due to neglecting the relationship between the user and the bio-devices, worn or implanted. This man-device link happens to be very powerful both at physical and psychological level, whenever it occurs. Thus, the biodesigner is supposed to think about the best ways to bring several devices features into harmony with users' body, with their daily lives and their lifestyle.

Naturally, medicine is not the only field where the advantages of this new approach are proved. But it's expected to be one of the most effective because of the deep involvement with several spheres of personality, far beyond considering a person only a patient or a user.
Moreover, such aspects of creativity in design become very clear and promising once the technology provides capabilities to interact with the human body at every level, even for total connection of implanted devices, for example. Hence, one of the main objectives for Biodesign is likely to identify the role of industrial design in the process of design and application of micro (MEMS) and nano-devices (NEMS) for bio-robotic and biomedical systems, setting and enhancing methodology and tools. Besides, the design activity is extended towards all the devices used inside and outside the human body as integration or aid. The MNT, for instance, are particularly promising for developing biosensors and therapeutic applications to implant (see cell drug delivery [9]) where the tissue interface and device handling are fundamental. Many other system applications require the Biodesign approach in monitoring physiological parameters, optimizing wearable solutions, analyzing the context functionality of telemedicine devices. We use to define the human body by integration of body areas (see Figure 1).

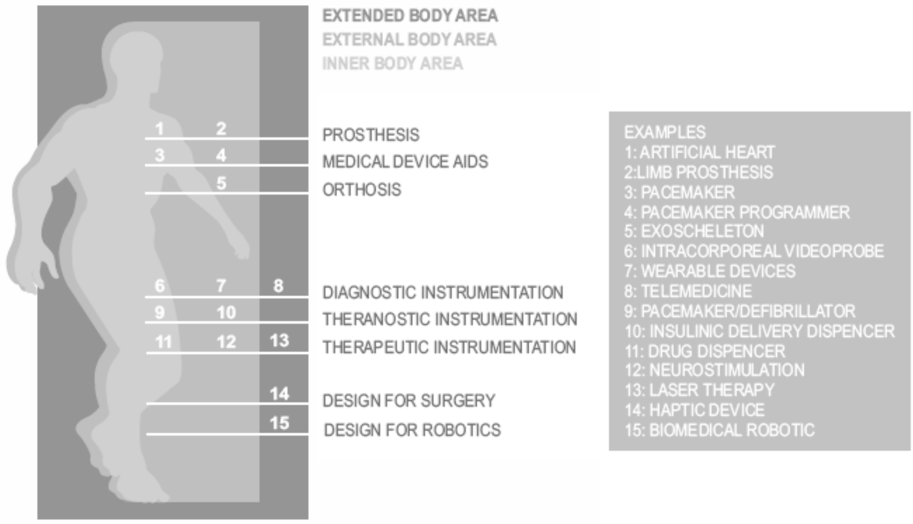

Figure 1. Biodesign's fields

In this research context becomes significant to understand how every player of health care field (designers, doctors, users or non-professionals) take part in the application, given that the interaction with devices is always a creative process. Apart from the basic contribution of engineering staff, this process of integration involves the concept of user and doctor's participation to the design process – a concept that becomes very important for any so-called smart product, marked by optimization and customization interventions given by the users in addition to large performances in sensing features [7]. The design process, with analytical and synthesis phases, may be as well assumed as an experimental framework for developing bio-robotic devices, in an iterated feedback of practice and theory for generating solutions. In such frame we believe that would be interesting for multidisciplinary teams to define research methods not connected to the specialization of the each involved discipline, but to the solution of problems (see Vernadsky in [2]).

3 EDUCATION

Biosciences nowadays stand out among the most relevant disciplines for scientific and technological development. If on one side the health care is driving significant policies in research guidelines, on the other one the strong progress in biotechnology, for instance, provides a technological support for many new applications, not always effectively coupled with the needs of the healthcare system. Therefore, this potentially empowering synergy among bio-problems and technology should be achieved as an opportunity by both academics and industry in the educational plans.

The contribution of Biodesign in biosciences may be strategically interesting for investigation on biological system as an interdisciplinary research supply for technology development. Likewise, the research and design skills based on an appropriate interdisciplinary experience are surely fit for developing the potential innovation mainly due to micro and nanotechnologies, transferred into biorobotic and artificial devices applications with a strong industrial orientation.

This educational purpose should be probably followed by overcoming somehow stiff delimitations of technical fields, especially for cross-border sciences, like chemistry or material science. In particular, the industrial design may benefit from this enlarged interdisciplinary education in the field, for instance, of nanotechnology. Besides the EU 7thFP recommendations for interdisciplinary and nanotechnology development [4], this new science represents a very wide range expertise field and the research approach is generally shared by several different scientists because of the nature of nanodevices. Due to the scale of molecular structures, most of phenomena follow proper rules in electromechanical interactions, chemical and material properties, different physics and tribology on material interface.

So, first, learning the basic principles of these shared expertises is fundamental for an integrate approach to design a new generation of devices for organo-artificial coupling, prosthetic devices, biosensors and all previously outlined research fields[6]. The implementation of biorobotic microdevices, for instance, should take advantage from the skilful contribution of the Biodesigner in designing the working principle, in analyzing the living environment, especially for human body related activities, in introducing microdevices into the biomedical devices. These expertises should grow up from an experimental approach, sharing activities among experts in different sciences, and from an application based research.

Then, beyond the technical skills, another important part of the biodesigner education should builds the knowledge concerning safety, ergonomics and ethical issues. The risk analysis about introducing and testing innovative Biorobotics and biomedical devices for man healthcare are not supposed to be arranged without a deepen education and experience.

In brief, Biodesign approach for education purpose shares methodologies from design research [10] as discussed before, in order to analyze, understand and define requirements and solution for medical and biological problems, in particular for:

- *New procedures, instrumentation and system for prevention, diagnosis, therapy and rehabilitation.*
- *Concept and design of new prosthesis, artificial organs, medical device aids*
- *Resources and costs optimization concerning need and requirements*
- *New technology exploration and MNT exploitation in prosthetic devices*

So, as a main purpose of Biodesign Lab educational activity at Politecnico of Milan, some guidelines are followed for enhancing technology experience in biomedical problems, in particular:

- *strong scientific background for mechanics, physics and material science*
- *basic background in biology and medicine*
- *specific knowledge in design and process for micromachining and skill development in electronics, IT and system integration*
- *capabilities in analytical description and methodology for medical applications.*

The Biodesigner must be part of the whole design process, from the problem analysis and tools choice at the beginning, and not only collect requirements by medical people as a task. Many applications can be driven by technology exploration, "side-view" approach and interdisciplinary methods, especially for bio-inspired techniques. One way among others, is to gather students from the different disciplines involved in order to share their own background and attitude. The professionals and industry involvement is aimed to introduce in the educational process the experience of technical processes. Despite many projects and evidence in applications, thinking about methods and expanded education lacks in industrial design discussions about biomedical field activities. But technology developments in widely interconnected sciences, like MNT, are clearly suitable for an enlarged activity and research in industrial design.

Therefore, some examples are outlined in order to get a structure in education for Biodesigners, gathering experiences from Stanford University and Politecnico di Milano.

Course	**description**
Design Theory and Methodology	The objective is to enhance the critical approach of students in building knowledge and getting proper methodologies in biological and medical environment
Innovation in materials	The topics are particularly focused on new materials, high performance tissues, coupling organic tissues and production processes for smart materials
MEMS and NEMS Innovation	The main purpose is to promote concepts and innovation of MEMS application in human body context. Elettromechanical properties as well as physics principles for handling micro and nanostructured materials are subjects shared with many others fields experts. The exploration of innovation in nanotechnology is required.
System design and Wearable devices	Introduction to electronics and telecommunication issues.
Biomedical applications	In cooperation with clinics and hospitals. Introduction to medical design and prototyping. The student access laboratories and medical staff for getting *in field* experience.
From concept to business	The main purpose is to collect tools for market analysis, setting context requirements and manage the biomedical project as a business opportunity.
Modeling and engineering	Simulation of tissues, organs, body interactions; tools for prototyping and study product properties. Engineering and process knowledge is required to manage the industrial exploitation
Bio-products Design laboratory	In cooperation with Industrial Partners. Instrumentation, tools and methodologies are shared with students for applying technology, sensors and solution to a real problem. Project-based course.

Table 1. Courses in Biodesign

In Table 1 are shown only the core courses related to Biodesign (all complete table is funding in [7]). Besides the characterizing courses, the interdisciplinary education provides, in particular, many basic bioengineering subjects fit for technical experience in biomedical devices, i.e. instrumentation, biosensors, bio-signals and artificial organs. Then the applicative sessions in clinical context are coupled with courses for physiology and bio-mechanics for instance. Finally the management school should give the basic experience to exploit innovation and research in industrial context, especially for the product applications that represents the core purpose of industrial design.

4 CONCLUSIONS

The multidisciplinary contribution of the industrial design in biological related fields, ultimately the Biodesign contribution, is likely to provide articulated intervention levels in new technology development for human body applications. In microtechnology field, in particular, the acquired knowledge, experience and strong project tradition of industrial design should be acknowledged for two concurrent tasks: first, the general creative invention of new solutions by exploring technology opportunities, observing nature for life-imitating principles and formal concepts on new ideas. Second, the technical contribution in designing the devices themselves.
Pointing at the described opportunities for new technologies exploitation, it is necessary, in the short term, to put in action more people on survey and research tasks in multidisciplinary fields, where the industrial design may play an important role. The creation of interdisciplinary educational programs for all the involved disciplinary sectors should give a strong impulse for the development of a common scientific language that allows the designer to effectively cooperate with the other disciplines that cope with the cutting edge new technologies, like MNT.

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