Bionics in Engineering - Defining new Goals in Engineering Education at "Politehnica" University of Bucharest

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Abstract **- During the past years, bionics, a new discipline, which is dedicated to the transfer of principles of construction, regulation, interaction and organization in biology into innovative technical solutions, is attracting significant interest from various industries. Based on this request for bionic expertise in engineering, the faculty for teaching engineering in foreign languages (FILS) at "Politehnica" University of Bucharest started a course in bionics in SS 2007, which was supported by the expertise of the German "Bionik-Kompetenz-Netz", one of the leading organizations in bionics. This is the report of the considerations involved in the course concept, the first experiences with the student's acceptance, some conclusions and future perspectives for extending bionics activities at "Politehnica". In order to avoid any confusion, considering overlapping or mixing up with other bio-disciplines related to technology, the report is starting with a short introduction, explaining the principles of bionics and providing a clear definition of the field.**

Index Terms - Bionics in engineering education, Bionik, International Cooperation, Biology

INTRODUCTION

Bionics as an emerging field at the interface of biology and the world of classical engineering, is gaining more and more acknowledgment and interest from various branches of industry and economy. The already wide spread, but still increasing application of bionic concepts and strategies in product and process development will lead to an increased request for engineers, that are having a solid background knowledge in this field, accompanied by a consistent practical experience in the application of the tools and ideas offered by bionics. Based on these considerations, "Politehnica" University of Bucharest, the oldest and one of the leading technical universities in Romania, started in the summer semester 2007 the course "Introduction into Bionics for Engineers" offered to the students of the German stream within the faculty for teaching engineering in foreign languages (FILS). The further development of these activities will be based on an open cooperation with the German "Bionik-Kompetenz-Netzwerk"[1], which has been founded in 2001 in order to promote the new field and gather the forces of the major national players.

In order to understand the general approach of bionics and its benefit for modern engineering, but also to avoid some misunderstandings and confusion because of interferences with terms like biotechnology or bioengineering, a short introduction into the fundamentals and principles of bionics, as well as its definition will be presented first.

WHAT IS BIONICS?

Although the historical roots of bionics can be traced back to the time of Leonardo da Vinci, the Italian middle age genius, or maybe even to earlier times, the definition of bionics as a modern research discipline, was given less than 15 years ago by Neumann and may be translated as: "Bionics is the scientific discipline, which is in charge with the systematic transfer of construction, process and evolution principles of living systems into technical applications"[2]. In extension of this definition, Neumann is additionally emphasizing the importance of including aspects of interaction between bio-systems or between bio-systems and their environment, which can be applied to economical and management systems as well. Nachtigall, one of the pioneers in German bionics[3], gave a short abstract of this formal definition by the sentence "Bionics is learning from nature for the creation of independent technical solutions"[4], which is underlining the important fact, that the major goal is not copying of nature. Bionics is not searching for master templates, that can be directly transfered into a technical solution, as it is done by

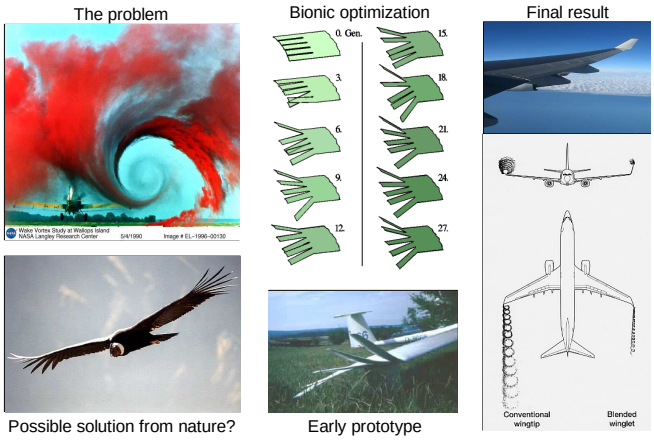

FIGURE 1
USING BIONIC METHODS TO MINIMIZE THE ENERGY LOSS DUE TO VORTEX GENERATION AT THE WING TIPS OF AIRPLANES.

biomimetics, which sometimes by mistake is used a synonym for bionics. Biomimetics can be regarded as that special part of the much broader bionic approach, where copying of nature is leading to useful and innovative technical solutions. The more than one century lasting intercourse between bionics and aviation technology might serve as a good example to demonstrate this important difference. Starting from the first attempts to construct machines, that can fly, researchers and engineers tried to borrow inspirations from nature, thus arriving in some cases at constructions, that looked like birds, bats or flying seeds, but not being able to achieve even a minimum percentage of the performance of their natural templates. The final breakthrough in aviation technology is based on the simple recognition, that a functioning technical solution can be achieved by the separation of the parts, which are generating the lift (wings) and the propulsion (engine). Nevertheless, airplane industry is still borrowing ideas from nature, like for instance by the introduction of the blended winglet, which is based on bionic ideas and research, derived from studies on the aerodynamics of bird winglets during gliding (FIGURE 1).

THE TWO STRATEGIC APPROACHES OF BIONICS

The former example about the development of the blended winglet is at the same time a typical example for the top-down approach of the bionic strategy, which means, that starting from a well defined technical problem, bionics is searching for analogous situations in nature, that might provide a solution for that specific problem. The mission of bionics, in this case, is the detailed analysis the of system, that is providing a potential solution, in order to understand, how this proposal of nature can be transformed into a technical system with similar properties. The whole process of development and optimization can be seen as a dialog between the worlds of technology and biology and, as it is demonstrated in FIGURE 1, there may be some early results, which appear very similar to the original proposal of nature, but the shape of the final technical solution (like the blended winglet) will in many cases not being traced back to its natural origin.

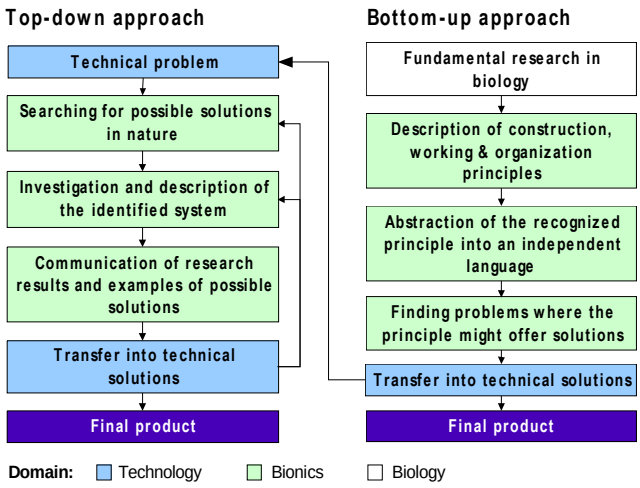

FIGURE 2
THE TWO STRATEGIC APPROACHES TO INTEGRATE BIONICS INTO TECHNOLOGICAL DEVELOPMENT.

The complementary strategy, the bottom-up approach of bionics, is not starting with a well defined problem, that has to be solved. It is starting with a (sometimes new) discovery in biological research, that is fully described and well understood. The recognized principle, then is translated into an abstract, formal and interdisciplinary description of the phenomenon, which is opening the pathways for the transfer into different fields of technology. A well known example for this approach is the so called "Lotus-effect", which was leading to many new applications in nano structured surface design.

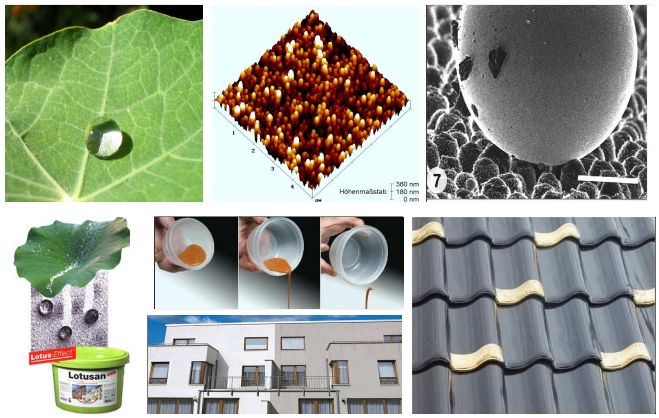

FIGURE 3
TOP: LOTUS-EFFECT AT WORK IN NATURE. BOTTOM: PRODUCTS BASED ON THE LOTUS-EFFECT (PAINT, SELF CLEANING FOOD CONTAINER, SELF CLEANING ROOF)

SOME FINAL REMARKS

In order to conclude this short introduction into bionics we may summarize: Bionics is not to be defined by a specific set of subjects or fields of applications, it is defined by a methodological approach, that uses two strategies, in order to transfer inventions of nature into technical solutions. In this way it is not covering those booming new disciplines like bio- and genetic engineering, nano-technology, or bioinformatics, but in many cases, the transfer of ideas and knowledge from biology into the world of engineering, is the starting point for the development of such new disciplines.

Therefore the development of a systematic approach, being in charge with the provision of an interface between fundamental research in biology and innovative engineering, was very important and now the time has come to implement appropriate teaching concepts in engineering education.

It also has to be emphasized, that there are growing and solid requests from various industries for bionic expertise in future engineers. It is more and more recognized that future technologies will gain at least a part of their innovative potential out of inspirations and ideas that are coming from nature. As an example for this trend, the presentation of the study of a bionic car by DaimlerChrysler in late 2005, can be mentioned here[5] (FIGURE 4).

FIGURE 4
BIONIC CAR PRESENTED BY DAIMLERCHRYSLER IN DECEMBER 2005

HOW TO INTRODUCE BIONICS IN ENGINEERING EDUCATION?

The introduction of bionics in engineering education is not a trivial challenge. Due to the novel character of the discipline the availability of approved or established concepts is rather limited and the best choice is, to rely on the example and experience of the the German BioKoN network [1], which might be seen as the most advanced institution for establishing bionic expertise.

Among all members of BioKoN, the University of Applied Sciences (Bremen, Germany) is in so far a the most interesting entity, as there, the course “International bachelor's degree in Biomimetics / Bionik” was established already in 2003 / 2004[6]. For Europe this is the first institution, which is awarding an official degree in the discipline of bionics, being also in concordance with the ECT-System and so, the curriculum of this course (FIGURE 5) might serve as a master template or example, that can be modified for the implementation of educational concepts in engineering science.

Semester						
1	2	3	4	5	6	7
Modul 1.1	**Modul 2.1**	**Modul 3.1**	**Modul 4.1**	**Modul 5.1**	**Modul 6.1**	**Modul 7.1**
Chemistry / Physics I	Chemistry / Physics II	Advanced Biology	Locomotion	Preparations for semester abroad	Project “Bionik” Theory I	Project „Bionik“ II
Modul 1.2	**Modul 2.2**	**Modul 3.2**	**Modul 4.2**	**Modul 5.2**	**Modul 6.2**	**Modul 7.2**
Mathematics / Informatics I	Mathematics / Informatics II	Physiology	Materials / Mechanics II	Semester abroad	Project „Bionik“ Praxis I	WPM*
Modul 1.3	**Modul 2.3**	**Modul 3.3**	**Modul 4.3**	**Modul 5.3**	**Modul 6.3**	**Modul 7.3**
Biology and Bionik I	Biology and Bionik II	Materials / Mechanics I	Finite Element Method I	Semester abroad	Advanced Materials science I	WPM*
Modul 1.4	**Modul 2.4**	**Modul 3.4**	**Modul 4.4**	**Modul 5.4**	**Modul 6.4**	**Modul 7.4**
Preparation-techniques I	Preparation-techniques II	Computer Aided Design (CAD) I	Measurement-techniques	Semester abroad	Exkursions	Bachelor Thesis
Modul 1.5	**Modul 2.5**	**Modul 3.5**	**Modul 4.5**	**Modul 5.5**	**Modul 6.5**	**Modul 7.5**
Communicative Competence I	Communicative Competence II	Communicative Competence III	Communicative Competence IV	Review of semester abroad	WPM*	Bachelor's Thesis

*„Wahl Pflicht Modul“ (WPM)
in Semesters 6 and 7 at least one of these modules (Module title 6.6 - 6.8 or 7.6 - 7.9) must be attended.

FIGURE 5
THE SCHEDULE OF BACHELOR IN BIONICS AT UNIVERSITY OF BREMEN, GERMANY (from: http://bionik.fbsm.hs-bremen.de/pages_english/st_modules.html)

BIONICS AT “POLITEHNICA” UNIVERSITY OF BUCHAREST

“Politehnica” University of Bucharest (UPB) is the oldest and one of the leading schools for engineers in Romania. In order to keep claiming this leading position and recognizing the importance of bionics in future engineering, the senate decided in December 2006, to implement a course in bionics, which should be the starting point for further activities in this field.

As there are at least no official activities in this field all over the country, infrastructures and resources have to be created and in the first step, a contact to BioKoN was established. Through the support of BioKoN, it was possible, to offer only a few months after the decision of the senate the course “Introduction into Bionics for Engineers”. The main goals of this course and all other activities related to it were:

- Verification of the student's interest and acceptance.
- Adoption and modification of the initial course concept according to the student's background knowledge, based on the direct feedback given by them.
- Establishment of contacts to other groups at UPB, in order to find contributers to a future network.
- Establishment of first contacts to industries, in order to include their feedback in all future activities.

Although the course was optional for the students, there were 19 inscriptions, which can be considered as an unexpected high value, as the overall experience is telling, that optional courses are not very well accepted, because the student's schedules are not offering much time for additional lessons. The feedback from the students during the course was positive and spontaneous and it will be evaluated in detail at the end of the semester by a questionnaire, which is addressing 4 different aspects of the course concept and its success in the perception of the students (FIGURE 6).

Except for a preliminary internal and still incomplete report[7], the detailed analysis of the evaluation is not yet available and will be published later.

The initial course concept, which was partially based on materials for an introductory course in bionics at the University of Applied Sciences (Saarbrücken, Germany), needed some modifications because of the inhomogeneous backgrounds of the students, that came from higher and lower academical years. As supplementary materials, the students received the slides for each lecture, which for the next course will be completed by printed booklet.

Concerning the establishment of academic contacts, in order to build up a network, or the establishment of industrial partnerships, it is still to early for some final statements. But, at least for industry related activities, it turned out, that there is a lack of information about bionics and so, it would be useful, to consider for the future also some courses like summer schools or weekend seminars for external participants. According to the experience of some BioKoN members, German managers discovered, that they can gain a lot of inspirations from bionic creativity trainings.

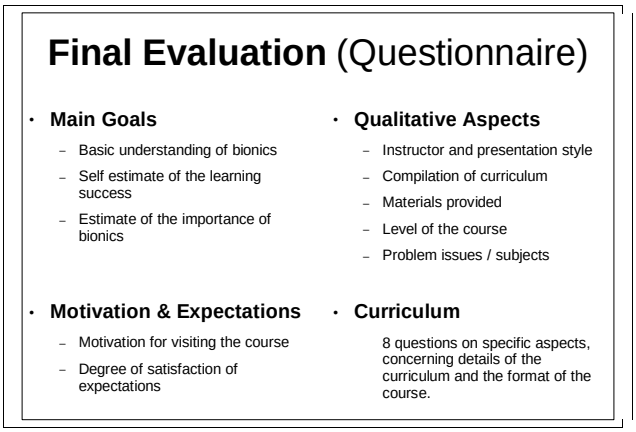

FIGURE 6
ASPECTS, COVERED BY THE COURSE EVALUATION ACCORDING TO THE STUDENT'S PERCEPTION

CONCLUSIONS & PERSPECTIVES

Based on the experience during the course itself, the information gathered by all other activities, related to the course, discussions with representatives from the university and industry and, especially because of the high acceptance and positive feedback from the students, the experiment of introducing bionics into engineering education at "Politehnica" has to be considered as a successful experiment. Especially the openness and willingness of the students, to enter into a new field, without having any idea about adventure they are stepping in, has to be appreciated.

Without waiting for the final evaluation at the end of the course in June, the following guidelines and perspectives for future activities in teaching bionics at UPB can be already deduced:

- A general introductory course, addressing all semesters and also different faculties should become mandatory for some streams.
- Additional courses, offering more specific, detailed and deeper insight have to be developed. Beside the classical lecture part, these courses also have to offer experimental modules and exercises.
- Because of the traditionally very solid background of the students in the fundamentals of engineering, like measurement, mathematics, physics and computing, all teaching activities should be focused more on the biological and experimental aspects of bionics.
- Especially the dialog with industrial partners will be continued and intensified, not only in order to include their requirements as much as possible in the concepts, but also to convince them to become partners, which will offer occasions to the students, to do some projects, which will become part of the curriculum.

So, the road map is in sight and fortunately "Politehnica" did not only make the right decision, it was also the right decision at the right time, because after joining Europe in January 2007, now the instrument of structural funds is providing the money that is needed, to establish an appropriate infrastructure for establishing a permanent competence in the field of bionics. Nevertheless, the implementation of a course that is awarding a full academic degree at UPB, might be a future option, but is not seen for the next 2 or 3 years.

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