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DEVELOPMENT AND PERSPECTIVES OF AGRICULTURAL ENGINEERING TOWARDS BIOLOGICAL/BIOSYSTEMS ENGINEERING

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1. Introduction

Agricultural mechanization has been ranked as one of the greatest engineering achievements of the 20th century by the U.S. National Academy of Engineering. Agricultural engineering played a vital role in that transformation. Many other traditional areas of agricultural engineering, such as soil and water, post-harvest and value-added processing, and structures and environment, have also made remarkable impacts to the agricultural production, the food industry and environmental stewardship. Agricultural Engineering has evolved into a broad bio-based engineering and technology scope and is defining a new discipline that will guide its future for many years.

To build on the past success and to further enhance the ability of the "agricultural engineering" discipline in its contribution to an evolving system including agriculture, food, environment and energy, the discipline needs a strategic decision to adopt a more holistic approach as depicted by its new discipline of "Agricultural and Biological/Biosystems Engineering (ABE)".

In this vision, the land grant functions of teaching, research and extension education as well as the faculty responsibility of service (including economic development) will continue. The overarching mission of ABE is to "integrate life and engineering for enhancement of complex living systems". Engineering is a process of design under constraints. The task of design is to systematically and computationally assemble and integrate resources to achieve certain operational and performance goals. Traditionally, engineering design in our discipline has been to enable and facilitate system operations that contain biological processes (this is the task of "bringing engineering to life"). Therefore, the biological processes and the knowledge of life (i.e. biological) sciences have been considered as "constraints" or "requirements". In our new vision, the added biological/biosystems engineering will also use life sciences as resources for engineering work (the concept of "bringing life to engineering"). The overarching goal of ABE work is to "enhance complex living systems" involving humans, plants, animals and microorganisms within the context of agriculture, food, environment and energy.

2. Domains of Agricultural and Biological/Biosystems Engineering

The ABE (as opposed to human health emphasized biomedical or bioengineering) disciplinary relevance and impact areas include:

- Bio-Based Processing and Production Systems;
- Biomass and Renewable Energy;
- Precision and Information Agriculture;
- Agricultural and Biosystems Management;
- Agricultural Safety and Health;
- Food Quality and Safety;
- Environmental Stewardship;
- Land and Water Resources;
- Spatially Distributed Systems;
- Structure and Facilities for Living Systems;
- Indoor Environmental Control;
- Bio-sensors, Bio-instrumentation, Bio-informatics, and Bio-nanotechnology;
- Intelligent Machinery Systems;
- Automation of Biological Systems;
- Advanced Life Support Systems.

3. Core Competencies of Agricultural and Biological/Biosystems Engineering

The key to the successful achievement of this vision lies in faculty expertise, as well as research and educational activities in the areas of automation, culture, environment and systems (i.e. the ACESys paradigm shown in Figure 1). The "culture" aspect of the

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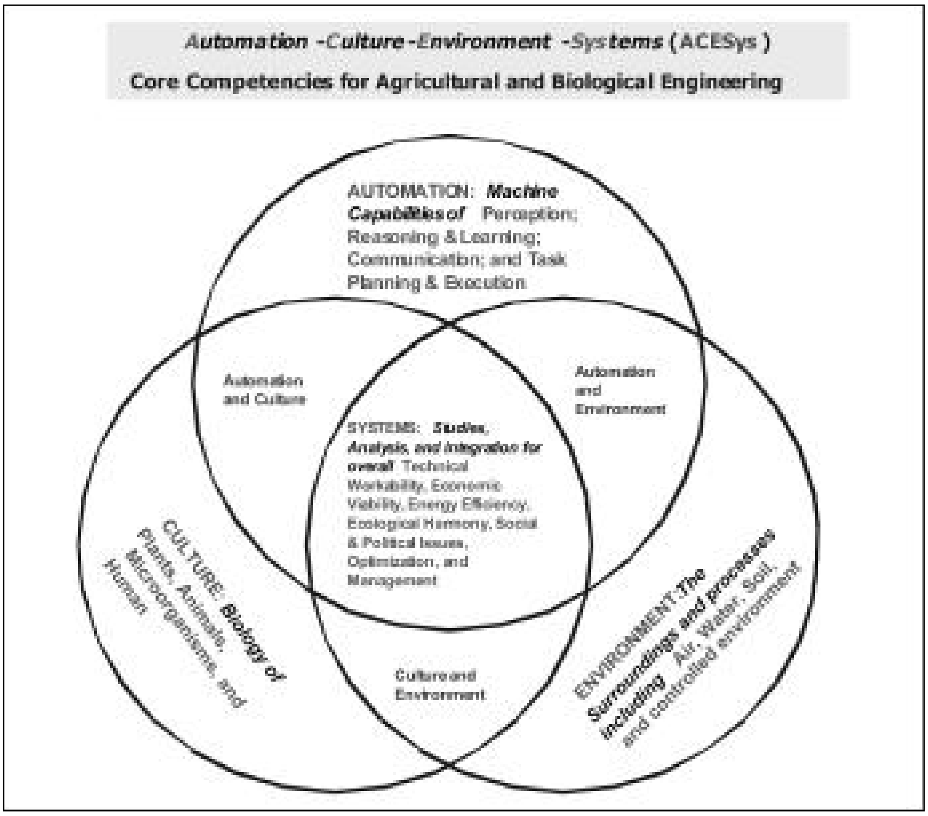


Fig. 1 - The ACESys core competencies paradigm.

ACESys paradigm accentuates the expanded biological emphasis of ABE. Therefore, an ABE academic unit needs to build a faculty that will provide complete and complementary expertise, as well as conduct research and educational programs following the ACESys paradigm.

Automation deals with information processing and task execution related to a system operation. The purpose of automation is to equip engineering systems with human-like capabilities of perception, reasoning/learning, communication and task planning/execution. Commonly seen automation topics are instrumentation, control, computerization, mechanization, modelling, machine vision, robotics, artificial intelligence, etc.

Culture includes the factors and practices that can directly describe and/or modify the growth and development of biological objects. The cultural factors, such as morphological and physiological conditions as well as genetic expressions are important in monitoring growth, development and functions of biological objects. The cultural practices may include operations which directly alter biological states and activities.

Environment encompasses the surroundings and processes of biological objects, which consist of climatic and nutritional, as well as structural/mechanical conditions. Understanding, delivery and control of environmental factors have been perceived as a major engineering challenge in agricultural production and bio-processing.

Systems analysis and integration is a methodology that starts with the definition of a system and its goals, and leads to the conclusion regarding the system workability (i.e. technical feasibility and practicality), productivity, reliability and other performance indicators for decision support purposes. The success of systems analysis relies on the effective use of information. Two key resources in systems analysis are the following:

1) information about individual system components as well as their interrelationships;
2) methods of information gathering and processing for creating value-added information.

In the past, agricultural activities mainly included on-farm production of plants and animals. Recently, systems approach to study agriculture has required that the entire food system (including the production of fresh materials and the consumption by end-users), the impact to the environment and the effective use of energy should be taken into consideration. Commonly investigated system level question about the food and agricultural system is the system impact on the 6 E's: Economics, Environment, Energy, Ecology, Efficiency and Education. The integration of biological, physical and chemical sciences with engineering and technology provides a powerful platform for addressing systems level issues relevant to an increasingly complex agricultural and food system.

4 Resolution of ASABE ED-210 Academic Program Administrators Committee

The membership of our primary professional society, American Society of Agricultural Engineers (ASAE), voted to change its name to the American Society of Agricultural and Biological Engineers (ASABE) in July 2005. ASABE ED-210 (formerly ASAE P-210) is a committee that consists of academic program administrators. During the annual international meeting of ASAE in July 2005 in Tempa, Florida, P-210 held a special meeting to discuss the impact of the current proliferation of academic department and program names. It was decided that the names and contents of educational programs would significantly impact five important issues:

1) curriculum and accreditation;
2) student interest and recruiting;
3) placement/industry recognition;
4) ranking and identity;
5) professional engineer licensing and professional society membership.

A list of action items were generated and discussed. They included:

1) select one common program name;
2) develop core elements and common competencies;
3) influence the change of the program names/definition;
4) avoid bioengineering as a name;
5) name programs that are accredited under the ABET agricultural criteria as agricultural engineering and those programs accredited under the proposed biological engineering criteria as biological engineering;
6) continue the discussion on names and how to influence local politics to achieve a common name.

Before the conclusion of the meeting, a motion was passed that P-210 affirms a goal that departments adopt agricultural engineering or biological engineering as their respective accredited undergraduate engineering program names. Our ACESys paradigm may provide a clear vision for future agricultural and biological engineering academic units and programs.

While the domains and core competencies mentioned above help frame and describe the discipline of ABE, one key contribution of the discipline is to effectively advance the bio-based economic engine, as shown in Figure 2, by paying special attention to systems level issues of the 6 E's.

5. Strategic Thrust Areas of ABE at Illinois

Effectively sustaining the cycle of this economic engine is essential for improving its effectiveness and competitiveness, optimizing its economic return, providing management capabilities, monitoring and ensuring intelligent use of resources, understanding the governing constraints, enabling creative productivity, interfacing with other economic sectors, identifying value-added opportunities and creating new economic activities for wealth and job generation.

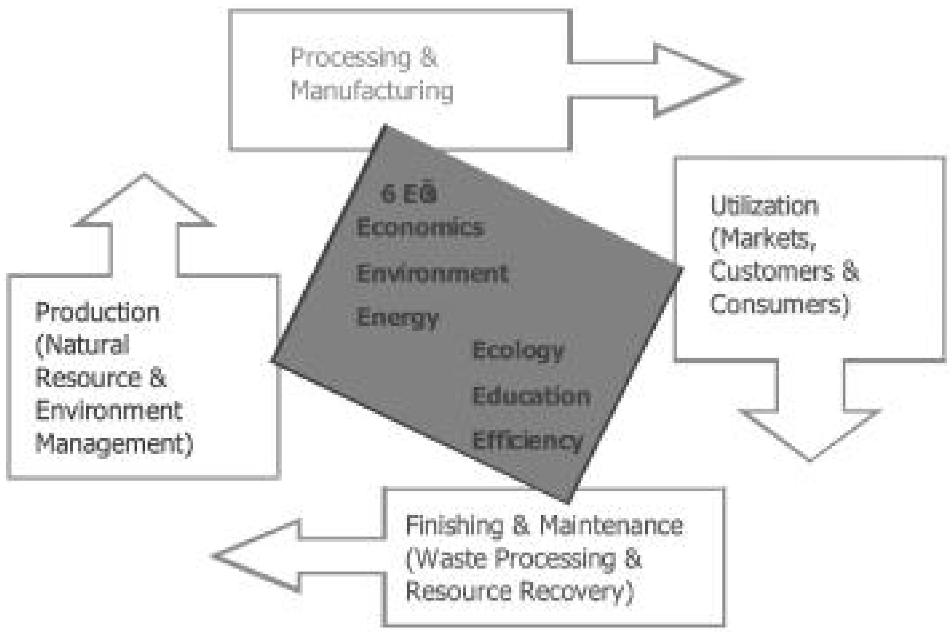


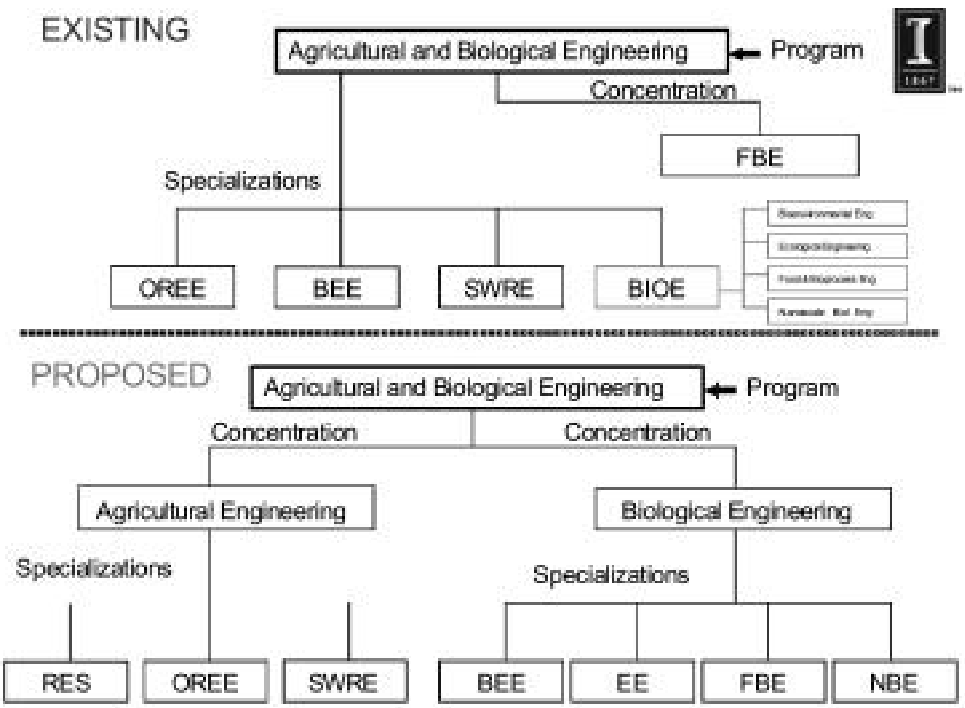
Fig. 2 - The Bio-based economic engine.

The following technical areas or initiatives are of particular importance in sustaining and advancing this very large and complex bio-based economic engine (each focus area incorporates systems management and safety/health dimensions):

1) Agricultural Automation, including machine intelligence of perception, reasoning and learning, communication, and task planning and execution;
2) Bio-Energy and Bio-Products, including production of bio-fuels, bio-power and bio-materials; example research and development activities are ethanol production, bio-diesel properties and engine performance, thermo-chemical conversion of biomass to crude oil, engineering solutions for biomass feedstock production, and systems integration and analysis;
3) Sustainable Environment, including information and analytical tools, processes, simulation and socio-economic considerations;
4) Biological Engineering, including biological nanotechnology (e.g., biosensors, nanotherapeutics with functional biological nanocomponents, etc.), programmable biotechnology (also known as synthetic biology, e.g. whole-cell biosensors, metabolic engineering, tools for molecular biosciences etc.) and biological device design (also involving the development of mathematical and information-based tools on the analysis and simulation of biological systems);
5) Systems Informatics and Analysis, including complex design techniques, decision support, early reliability measurement techniques, holistic agro-ecosystem perspectives, multi-scale modelling and sustainable development.

6. Development of Agricultural Engineering towards Biological / Biosystems Engineering

At the University of Illinois, a four-step process has been taken to develop the biological engineering undergraduate educational concentration (Fig. 3). Step 1 was to change the department name from Agricultural Engineering to Agricultural and Biological Engineering while maintaining the undergraduate program name Agricultural Engineering. In Step 2, a specialization of Biological Engineering was created within the Agricultural Engineering degree program (in addition to the existing specializations of Bioenvironmental Engineering, Off-Road Equipment Engineering, and Soil and Water Resources Engineering and concentration of Food and Bioprocess Engineering). A specialization signifies the technical emphasis of the educational experience and will not appear on the student's transcript. A concentration is a formally recognized curriculum within a degree program and will appear on the student's transcript. Step 3 was to change the degree program name from Agricultural Engineering to Agricultural and Biological Engineer-



FBE: Food & Bioprocess Engineering; OREE: Off-Road Equipment Engineering;
BEE: Bioenvironmental Engineering; SWRE: Soil & Water Resources Engineering; BIOE: Biological Engineering; RES: Renewable Energy Systems;
EE: Ecological Engineering; NBE: Nanoscale Biological Engineering

Fig. 3 - Existing and proposed ABE educational program at Illinois (Courtesy of Alan Hansen, University of Illinois).

ing (ABE). Step 4 is to develop a formal concentration of Biological Engineering within the new ABE degree program. As of April 2010, Step 4 is reaching the final approval by the university.

The Biological Engineering concentration integrates biology and engineering to provide solutions to problems related to living systems (plants, animals, humans, and microorganisms). Engineering biological systems vary widely in scale. At the molecular level, nanometer-scale devices consist of a few biomolecules inside individual cells. At the other extreme, regionally-scaled complex ecosystems depend upon multiple species of interacting living organisms. Such systems are becoming increasingly important in the areas such as synthetic biology, nanotechnology, bioprocessing, biosensing, bioinstrumentation, bioenergy, bioenvironmental engineering, and ecological engineering.

7. Conclusion

Bio-based economic systems are increasingly important; especially in translating biotechnological advances into practice. More and more biological sciences and engineering are integrated to effectively achieve the goals of bioeconomy. This integration has generated new opportunities for further advancements in both biological science and engineering. Almost all functional bio-based economic systems require contributions and collaborations from many disciplines, and frequently with engineering expertise catalyzing the integration effort. Agricultural and biological engineering is a discipline that is uniquely qualified to enhance complex living systems, involving agriculture, food, environment, and energy, by integrating life and engineering. The ACESys concept was developed to provide the overarching guidance for assembling necessary and complementary core competencies for the ABE discipline and profession.

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References

Department of Agricultural and Biological Engineering, University of Illinois at Urbana Champaign, Strategic Plan 2006-2011, Version 1.6, 2006.

Summary

Systems involving agriculture, food, environment, and energy (AFEE) have played, and will continue to play, a highly significant role in a very large scale bio-based economic engine. Agricultural and biological engineering (ABE) is a discipline that integrates life and engineering for enhancement of complex living systems. The strategic alignment between the advances of AFEE systems and the development of ABE discipline and profession is of great importance. Agricultural engineering and biological/biosystems engineering are synergetic in their problem domains and inseparable in their core competencies. At the University of Illinois, an automation-culture-environment systems (ACESys) concept and methodology has been applied to guide the identification, assembly, and integration of core competencies during the evolution from traditional agricultural engineering towards the inclusion of biological/biosystems engineering into a more comprehensive ABE program.

Keywords: Agriculture, Food, Environment, Energy, Domains, Core Competencies, ACESys.