From agricultural engineering and forestry engineering to biomechinfotronic engineering

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Abstract: The deterioration of global environment, decreasing of biological diversity, increasing of natural disasters, exhausting of biological resources and acceleration of desertification emphasize the need to provide the human-beings with the suitable environments. Nowadays, precision agriculture and precision forestry have been emphasized to obtain the maximum output with minimum input and the least impact on the environment, so agricultural and forestry engineering systems require multi-disciplinary design groups to deal with some common interests and the concept of biomechinfotronics is needed. The word "biomechinfotronic" is introduced to describe the multidisciplinary aspects of this complex system. In the paper, the prospects, mission analysis, education system, research areas of biomechinfotronics are studied. The particular characteristics of biomechinfotronics are the synergistic integration of biological engineering with mechatronics, bioinformatics, infotronics, bioelectronics and intelligent computer systems for conducting common research and development and for recruiting and training students with wide specialties.

Key words: agricultural and forestry engineering, precision agriculture, precision forestry, biomechinfotronics, multi-disciplinary, sustainable development

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1 Introduction

Industrialization and the economic development are not the whole goal of social development because the world is confronted with both developing the economy and protecting the environment, Global large-scale measures for pollution prevention and control as well as environmental protection are crucial elements. "What is the use of giving, if not to strive for noble causes and to make this muddled world a better place for those who will live in it after we are gone?" Winston Churchill once asked. The Former United Nations Secretary-General Kofi Annan said at a closing press conference in the World Summit on Sustainable Development (held in Johannesburg), "This Summit makes sustainable development a reality. This Summit will put us on a path that reduces poverty while protecting the environment, a path that works for all peoples, rich and poor, today and tomorrow." But the deterioration of global environment, decreasing of biological diversity, increasing of natural disasters, exhausting of biological resources and rapid increase of desertification are presently the pervasive concerns of governments which have pushed to consider how to provide human-beings with the suitable environments for survival and development.

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Sustainable development is one of humanity's biggest challenges in 21st century. Common understanding of the global citizens, of the key role of agricultural and forestry systems should pay a key role. Meanwhile, agricultural and forestry engineering systems require multi-disciplinary design groups which should be related to the biological science and other advanced technologies. For example, ASAE (the American Society of Agricultural Engineers founded in 1907) has successfully been changed to ASABE (the American Society of Agricultural and Biological Engineers)[1].

Nowadays, precision agriculture and precision forestry have been emphasized to obtain the maximum output through the minimum input and the least impact on the environment[2-4]. Then the importance of biomechinfotronics (this is a new word in the English language used for the first time in this paper) should finally be a focused subject to keep the sustainable development pace with times in the research, education and development of agricultural and forestry engineering for the purpose of sustainable development utilizing science and technology.

The objectives of this paper were to analyze the prospects of biomechinfotronic engineering, the definition, the mission analysis, the education system, and the research areas of biomechinfotronic engineering based on the introduction of mechatronics, bioinformatics, infotronics and bioelectronics.

2 Why Biomechinfotronics?

2.1 Traditional agricultural and forestry production

Traditional agriculture and forestry production relied mainly on animal draft implements, and hand tools like the hoe and reaping hook to manually plant the crops, feed livestock, fishing and shrimp harvest, and simple processing of agricultural products for self-support or commercial exchange. Traditional production of agriculture and forestry were highly dependent on natural resources and weather conditions.

2.2 Present agricultural and forestry production

Globally competitive agricultural and forestry production systems have recently appeared. Provision of sufficient high-quality food and sufficient plant and animal fiber at affordable prices, as well as the creation of employment and entrepreneurial opportunities, are the challenges facing the present agricultural and forestry production[5]. Modern agriculture and forestry means sizeable-scale planting, husbandry and comprehensive processing without environmental pollution through high-tech management.

2.3 Precision agriculture and precision forestry

There are several phases for precision agriculture, such as precision farming, site-specific crop management, prescription farming, and satellite agriculture. “Precision agriculture is a phrase that captures the imagination of many concerned with the production of food, feed, and fiber. The concepts embodied in precision agriculture offer the promise of increasing productivity while decreasing production costs and minimizing environmental impacts. The precision agriculture conjures up images of farmers overcoming the elements with computerized machinery that is precisely controlled via satellites and local sensors and using planning software that accuratelly predicts crop development” [6].

A systematic diagram of precision agriculture is summarized as shown in Figure 1. The benefits of precision agriculture are summarily the highest yield with the least input and the least environmental impact.

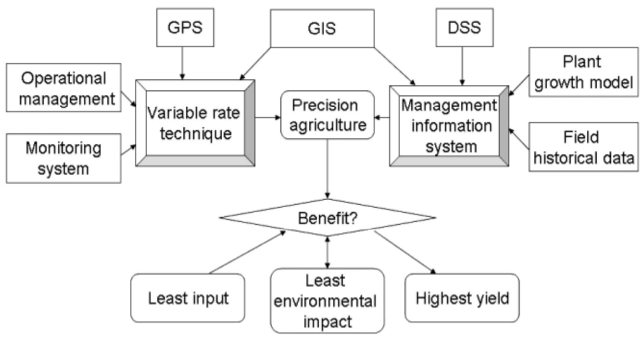

Figure 1 Systematic diagram of precision agriculture

Forestry production factors are dramatically varied in temporal domain and spacial domain because forestry production consists of different production operations to share the time and resources. So forestry production is a pretty complicated systematic engineering to harmonize the resource limitation and the economic forest products cycle, and the topic of precision forestry has been studied by many researchers for the last century or so.

Bare[7] said in the welcome remarks for the First International Precision Forestry Cooperative Symposium ”Precision Forestry deploys high-resolution data to support site-specific tactical and operational decision-making. This allows for highly repeatable measurements, actions, and processes to grow and harvest trees, as well as to protect and enhance riparian zones, wildlife habitat, esthetics, and other environmental resources. Precision forestry provides valuable information linkages between resource managers, the environmental community, and processors. It links the practice of sustainable forestry with conversion facilities and markets to produce the best economic and environmental returns”.

Figure 2 shows the framework of a precision forestry engineering system which has been developing in Nanjing Forestry University sponsored by National Natural Science Foundation of China[8,9].

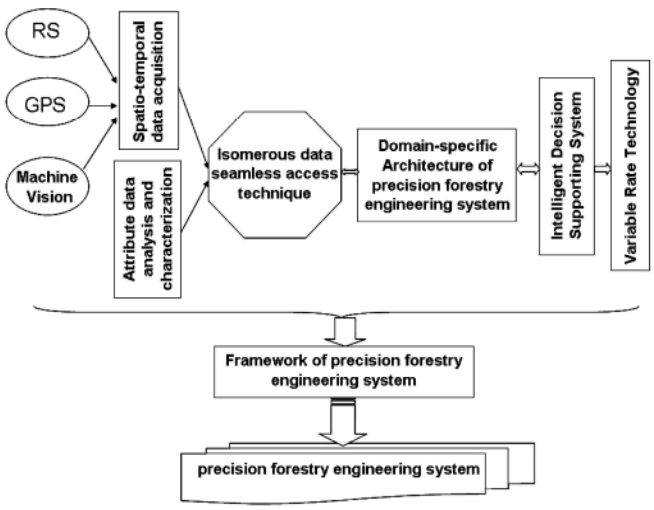

Figure 2 Framework of precision forestry engineering system

As the modernization of agricultural and forestry production and the development of computer integration technique, the island of automation or island of information could be jointly integrated to create an integrative environment for acquisition, transportation and processing of information. In summary, the goals of precision agriculture and forestry are to realize the least resource input, the least environmental impact and the highest agricultural and forest output, in which all the agricultural and forestry activities are integrated systematically to ensure the smooth integration of resource flow and information flow on the spatial-temporal scale.

Obviously, precision agriculture and precision forestry need multi-disciplinary knowledge to meet the sustainable development strategies.

2.4 From AE to ABE

ASABE[1], which comprises about 9000 members in more than 100 countries is an educational and scientific organization dedicated to the advancement of engineering applicable to agricultural, food, and biological systems. It has been successfully changed from ASAE. Recently, most of the leading universities in USA have changed Department of Agricultural Engineering (AE) to Department of Agricultural and Biological (or biosystems) Engineering (ABE) Examples include, University of Illinois at Urbana-Champaign, Cornell University, University of California at Davis, Ohio State University, Texas A&M University, Iowa State University as well as many others.

According to ASABE, agricultural, food and biological engineers develop efficient and environmentally sensitive methods of producing food, fiber, timber, and renewable energy sources for an ever-increasing world population. The Society has input from the following divisions and institutes, which represent ASABE's broad technical specialty areas: biological engineering, food and process engineering, information and electrical technologies, power and machinery, soil and water, structures and environment, ergonomics, safety and health, and other emerging areas. These technical areas clearly show the necessary integration of many disciplines.

3 Biomechinfotronics analysis

Crops and trees only have the differences of herbaceous plant and woody plant material, and all the livestock and fishes are animal with only the status differences in the taxonomy. All plants and trees and available wild propagation resources are derived from organic material. How to deal with crops and trees, livestock and fishes, and all the agricultural and forestry production activities needs multi-disciplinary knowledge of biomechinfotronics which consists of mechatronics, bioinformatics, infotronics, bioelectronics and other emerging subjects.

3.1 Mechatronics

The word mechatronics was first coined by a senior engineer of a Japanese company, Yaskawa, in 1969, as a combination of "mecha" of mechanisms and "tronics" of electronics and the company was granted the trademark rights on the word in 1971. The word soon received broad acceptance in industry and, in order to allow its free use, Yaskawa elected to abandon its rights on the word in 1982. The word has taken a wider meaning since then and is now widely being used as a technical jargon to describe a philosophy in engineering technology, more than the technology itself. For this wider concept of mechatronics, a number of definitions have been proposed in the literature, differing in the particular characteristics that the definition is intended to emphasize. The most commonly used one emphasizes synergy: Mechatronics is the synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacture of products and processes[10].

In biomechinfotronics, many agricultural and forestry machines need to be improved mechatronically to achieve the goal of mechatronics.

3.2 Bioinformatics and Bioelectronics

Informatics is the creation, development, and operation of databases and other computing tools to collect, organize, and interpret data[11]. The term, bioinformatics is often used interchangeably with computational biology which uses computational and mathematical tools to advance the biological research. As a result of development of computing technology and wide-spread use of internet, bioinformatics has an essential role in the collection, treatment, restoration, distribution, analysis, and annotation of biological research data generated by high-throughput experimental technologies. Bioinformatics developed as a new interdiscipline is one of the subjects which plays a very important role in gene discovery, genetic diagnosis of diseases, prediction of protein structure. “The ultimate goals of bioinformatics are to abstract knowledge and principles from large-scale data, to present a complete representation of the cell and the organism, and to predict computationally systems of higher complexity, such as the interaction networks in cellular processes and the phenotypes of whole organisms” [12].

Bioelectronics is a novel subject developed from information science and life science and is the study of the interface between biological and electronic systems[13]. Thus, bioelectronics, as a field which becomes more and more important for bioengineers related to bio-sensors on the macroscopic and nanometer scales, will attract more attention and gain greater development in the future.

Deservedly, the application of bioinformatics and bioelectronics will greatly speed the development of agricultural and forestry production for elaborately exploiting agricultural and forestry products and extending the application areas of agricultural and forestry bioinformatics.

3.3 Infotronics

As the amount of production information increases, it is possible for farmers to use precision agriculture to make their production systems more efficient. The greatest challenge for precision agriculture today is applying the information to support decision making in the field. One study on development of an "infotronic" system involves linking computer and wireless technology to deliver information from the farm office to the field according to the concept described by Zhang[14]. An on-tractor computer system can be developed that is universally installed. This computer "sees" the surrounding environment using sensors. The data gathered through these sensors are combined with data from a wireless transmission received from a stationary computer with an Internet connection. With this information, the on-tractor computer decides what to do and sends a command to major implements to make the necessary change automatically. Working much like a cellular phone, the computers can communicate for a distance of up to 1.5 miles (2.4 km) and the distance will increase as new technology becomes affordable. This system will allow use of a large amount of information from various sources to support precision agriculture because the data will be sent to the tractor instantly.

In biomechinfotronics, the technologies related to infotronics include GIS, GPS, RS, IDSS, VRT and other information and electronic technologies.

4 Mission and measures to develop biomechinfotronics

4.1 Mission analysis of biomechinfotronic engineering

The multidisciplinary effectiveness can be emphasized in the particular characteristics of biomechinfotronic engineering to promote the intersection, pervasion, merging and innovation of natural sciences, social sciences and humanities and to cultivate the abilities for students to analyze and solve concrete problems independently.

Biomechinfotronic engineering means the synergistic integration of biological engineering (including agricultural and forestry engineering) with electronics, mechatronics, infotronics, bioinformatics, bioelectronics and intelligent computer control in the design and manufacture of bio-products and processes.

The biomechinfotronic engineering program develops students with a comprehensive education for engineering careers in industries, consulting, government, and academia, which provides a combination of courses in engineering theory and application for students seeking careers in agroforestry production, bioprocess systems, environmental protection and product utilization.

4.2 Education system of biomechinfotronic engineering

The course outlines of biomechinfotronic engineering are suggested including non-technical courses, courses for sci-tech knowledge basis, courses for basic specialty technologies, courses for key technologies, practical projects, open seminars and other electives, as shown in Figure 3.

Non-technical courses include philosophy, economics, business administration, law, language(s) and other related courses.

Courses for sci-tech knowledge basis include mathematics, physics, chemistry, computer science, mechanics & thermology and other related courses.

Courses for basic specialty technologies include engineering graphics, instrumentation & measurements, microelectronics, electrotechnics, mechatronics, applied machine vision, control and automation, data processing technologies, mathematical modeling, general biology agroforestry science, digital communications, biochemical engineering, ergonomics, botany and agronomy, forestry engineering, and other related courses.

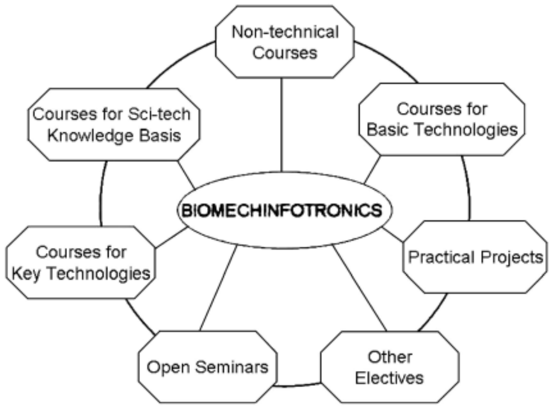

Figure 3 Course outlines of biomechinfotronics

Courses for key technologies include 3S technique, environmental protection for plants and animals, engineering for bioprocessing and bioenvironmental systems, robotics, analysis of bio-based systems, agroforestry machineries, biomass energy engineering, food processing engineering, zymolysis engineering and equipment, and other related courses.

Practical projects include honor projects, special problems for solving a biomechinfotronical problem, project laboratory, undergraduate thesis or design project, cooperative education practice (work in groups), ……

In open seminars, some related scientists can be invited to give students the presentations on related cutting-edge technologies[15].

Other electives include courses on engineering ethics, research orientation, project management, and other related elective courses.

4.3 Research areas of biomechinfotronics

Research activities enhance teaching and student understanding. Three-in-one combination involving teaching, research and production will help the development of biomechinfotronics for motivating teachers and students to look at different area's knowledge and technologies to develop a new biomechinfotronic product based on multi-disciplinary knowledge.

The research areas of biomechinfotronics can be systematically studied through the chain of technologies, the life cycle of organism, and the industry sectors for the agroforestry ecological system, which are described as follows.

1) The research areas of biomechinfotronics through the chain of technologies include (not limited) data acquiring and processing, IDSS, 3S, digital control & microcomputer control technique, automation and artificial intelligence, mechatronic and infotronic engineering, measurement for biotechnique, biocybernetics, biotransformation technology, efficiency evaluation, and so on Then some unique technologies in biomechinfotronics will be developed based on the integration of multi-disciplinary knowledge as the development of related advanced technologies.

2) The research areas of biomechinfotronics through the life cycle of organisms include (not limited) organism cultivation, engineering and technical measures for growth of organism, seeding engineering, land cultivation and preparation engineering, soil and water, crop management and plant protection, safety and health, environment control of agricultural and forestry production, deep-processing engineering of post-harvest agroforestry products.

3) The research areas of biomechinfotronics through the industry sectors for the agroforestry ecological system include (not limited) seed business, production and distribution of pesticides and fertilizers, trade of agroforestry products, manufacturing and business management of agricultural and forestry machineries, agroforestry information industry (such as database, e-business, GPS, GIS and RS services), bio-mass energy industry, and other potential industries.

5 Summary

Facing the deterioration of global environment, decreasing of biological diversity, increasing of natural disasters, exhausting of biological resources and acceleration of desertification, sustainable development has become the common understandings for the global citizens. Agricultural and forestry engineering systems require multi-disciplinary knowledge and the precision agricultural and precision forestry has been emphasized to obtain the maximum output through the minimum input and the least impact on environments. Then the importance of biomechinfotronics will be extended as the advancement tendency of science and technology. In this paper, the prospects of biomechinfotronics are analyzed after analyzing the traditional agricultural and forestry production and the existing situation of present agricultural and forestry production. The definition is intended to emphasize the particular characteristics of biomechinfotronic engineering which is the synergistic integration of biological engineering (including agricultural engineering and forestry engineering) with electronics, mechatronics, infotronics and intelligent computer system in the design and manufacturing of bio-systems and processes. Then the mission analysis, the education system, the research areas of biomechinfotronics were inverted into an outline of biomechinfotronics after the introduction of mechatronics, bioinformatics, bioelectronics and infotronics etc which will meet the requirements of social sustainable development. The subject of biomechinfotronics may be emphasized and some practical procedures may be encouraged including education system and research activities.

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