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An Outlook on Digital Agriculture

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ABSTRACT

There has been rapid transformation from traditional agricultural husbandry to modern agriculture. Digital agriculture is fundamental to the understanding of agricultural information systems and architecture. The strengthening of digital agriculture will greatly enhance agricultural technology revolution and a country's competitiveness in the WTO. To implement digital agriculture, the frame system of digital agriculture is required has to be studied. In accordance with the theory and technology of digital earth and in combination with the agricultural reality of contemporary agricultural sciences, this state-of-the-art review article outlines the frame system of digital agriculture and its limitations and benefits.

Key words: digital agriculture, digitized agricultural machinery (DAM), central processing systems (CPS), agricultural models, digital earth

Introduction

The development of international agriculture has experienced several main stages: primitive agriculture stage, traditional agriculture stage and modern agriculture stage. Undertaking some easy work by stoneware is one of the main characters of primitive agriculture. During the traditional agriculture stage, humans invented ironware and began to produce using tools made of iron and wood. The productivity was improved significantly. While during modern agriculture stage, advanced agricultural machines were used and agricultural economy made great progress. The character of current agriculture depends on information processing by the digitalization of information. The concept of Digital Agriculture is a turning point to normalize and boost the development of international agriculture. The Digital Agriculture is featured by digitization of agricultural activity driven by digits. It aims to build an integrated agricultural system, which combines data collection, data transmission, data processing and digital control of machinery together to realize the digitization, networking and automatic operation of agricultural activity.

Framework of Digital Agriculture

The framework of Digital Agriculture is composed of the following parts:

- Basic information databases of agriculture to provide basic information about farmlands, soil resources, climate conditions, social economy background to secure agricultural activities closely related with the whole society.
- Real-time information collecting system for monitoring of agricultural activities and update of databases made up of digitized information collectors responsible for the collection of meteorology, vegetation and soil information on ground, airborne or satellite based sensors.
- Digital network transmission system to accept the collection of information and the distribution of commands.
- Central processing system (CPS) based on GIS, agricultural models and expert systems to analyze the
collected information to make feasible decisions, and then to send out control commands to direct the work of digitized agricultural machinery.

- Digitized agricultural machinery (DAM) include digitized sowing device, digitized water and fertilizer control devices, digitized harvesting device based on data driven control systems to support digital networks, GPS and GIS, digitized agricultural machinery to implement the commands of CPS, and return processing results directly or through the real-time information collecting system.

Digital agricultural system determines the planting plan of a year according to the basic information databases monitors the growth dynamism of crops and provides soil structure, water content, disease, meteorology and other important information by information collecting system. CPS analyzes all kinds of information and makes reasonable decisions. Under the direction of CPS real-time data driven control mechanism to operate agricultural machinery to finish series of work, such as sowing, water or fertilizer controlling, harvesting, and return the results to CPS. CPS makes the overall analysis report. Digital Agriculture adheres to the integrative development of each part. Only when all the parts tie closely and develop cooperatively, only then Digital Agriculture is constructed. Any part or several parts developing separately can’t be called Digital Agriculture.

The Demand of Agricultural Modernization

To develop Digital Agriculture is the demand of agricultural modernization. On one hand, there are more and more people in the world, and resource for each person is limited. With the increase of population, conflicts between people and farmland, between people and food supplies will be rigorous. On the other hand, the level of resources utilization may deteriorate the environment and aggravate the conflicts existed. To realize the destination of sustainable development it is necessary to reclaim traditional agriculture, speed up the building of agricultural modernization, and to improve level of resources utilization and labour productivity. Digital Agriculture attempts to reach the destinations of saving land, saving water and saving fertilizer. It is s a key point to realize agriculture modernization.

The agricultural sector is being transformed into an industry of major importance that must rely heavily on computer-integrated management and advanced control systems (Sigridis et al., 2001; Young and Chotai, 2001; Albright et al., 2001). These technologies are becoming essential components of the next generation of plant and animal “factories” in the twenty first century. Efforts are being embarked on to survey the technological landscape and recognize trends shaping this forthcoming application field. Modern agriculture is becoming increasingly dependent on computer-based systems, automation, and robotics that are taking over many of the monotonous tasks formerly performed by humans, with superior performance in most cases. To manage the increasing complexity of agricultural systems, increasingly complicated methodologies are required. This has given rise to the promising field of precision agriculture, where the goal is to improve the efficiency of operation of agricultural enterprises, as well as the quality and consistency of products, by compensating for the imprecision and uncertainty of the environment. These objectives result in new and challenging problems—problems that can only be resolved by applying advanced information and control technologies to production management of processes and farms.

Agricultural systems are beginning to use many of the advanced methodologies and tools of industrial automation, modern control theory, and manufacturing processes and communication technologies. In addition, the biotechnology revolution promises dramatic improvements in production efficacy to meet social and societal concerns. The systems engineering is taking on the challenges and complexities involved in managing complex agricultural systems, real time radio frequency identification and supply chain management and is actively pursuing systems capable of that delicate property, intelligence. Such interdisciplinary activity leads to more effective agricultural systems that will be essential for sustainable, quality production in the twenty first century.

Perspective

Agriculture is the oldest industry, dating back to the wandering age. It initially depended solely on human labor, then tamed animal power, and followed next by dependence on mechanical developments such as steam/diesel-engine tractors and mechanical implements with hydraulic power where control was needed for attached implements. To date, most mechanization problems have been solved from the mechanical point of view. The solution of unsolved problems depends on further improvements those require the replacement of human intelligence to meet the needs for greater autonomy in more unstructured and uncertain environments. Human intelligence entails sensing, perception, prediction, planning, proactive response, and feedback.
Promising fields in this context include mechatronics, complex system automation, and large-scale optimization. Necessity is driving the assimilation of information technologies into agricultural technologies, whether in the form of a machine, a process controller, or a planning and management system, or a real-time supply chain network. This is obvious from the shift of ongoing academic and industrial research in this field, as presented in the articles cited in the reference.

Recent research has resulted in advances in all technologies bound to the closed loop as well as to the outer loops necessary to meet higher self-sufficiency and meticulousness. The information components necessary to deploy advanced controls and computational intelligence in crop production include a variety of forms such as dynamic data driven operational models, fuzzy reasoning, and neural algorithms, as well as technologies and implementation platforms such as mechatronics, networked systems, and robotic systems.

*Precision Agriculture*

Severe global competition with sharp price increases for raw agricultural products and heightened concern about the environment force farmers toward more appropriate use of resources for field crop production. In this respect, manufacturers, in close cooperation with leading research groups, began developing intelligent agricultural machines for precise and site-specific field operations, integrating mechanical, electronic, computer, and information systems. De Baerdemaeker et al., (2001) describe advanced mechatronic designs for three different mobile agricultural machines. A yield-mapping system for a combine harvester requires the design of the necessary sensors and processing of the acquired data. The latter includes aspects of filtering, elimination of unusable data, and compensation for machine dynamics. To reduce chemical inputs for plant protection, field sprayers are equipped with an intelligent selective spraying system. Optical sensors, detecting weeds among field crops, activate the appropriate pulse-width-modulated nozzles, mounted on the spray boom. The nozzles are correctly positioned in the field by stabilizing the spray boom with an active suspension. To improve and ease field operations, especially in row crops where the distance between rows and between plants within a row must be extremely precisely regulated, the steering mechanism of the agricultural machine is controlled by a reliable navigation system. The latter fuses data from several dead-reckoning sensors and in combination with global positioning systems. The communication system is the backbone for the tractor-implement as well as for the tractor-farm computer transfer of the large amount of data needed for precision agriculture. Control problems in the high-precision spreading of liquid manure are also addressed.

Recent advances in sensing, information, automation, and control technologies are providing researchers with means to explore previously unanswerable questions regarding plant physiological requirements. The ability to provide specialized environments, together with emerging diagnostic techniques for cellular differentiation, segmentation, and elongation, as well as whole-plant imaging, open further avenues of research. The fruits promised by this research include improved basic understanding of physiological processes and enhancements of our ability to apply this knowledge in efficient production control systems. Domain knowledge from research results must be coupled with technological implementation to ensure fast utilization; the demands for shortening product life cycles need to be addressed. Although no one can claim that intelligent control is a final answer for every conceivable control problem in agriculture, it must be seriously considered in future developments. The objective here is to make use of the tolerance for imprecision and uncertainty that are standards of computational intelligence techniques while incorporating characteristics of the agricultural environment under a requirement for rapid implementation. Given the power of soft computing and the wide acceptance of conventional manufacturing and control approaches, the question arises as to how to best benefit from both worlds. At the level of management, many production operations are event based, and the need for conflict management and efficient scheduling has become apparent. Manufacturing technologies such as discrete-event systems and the game theory must move around to field production and supply chain management operations. Can we develop solutions using hybrid systems to realize new control accomplishments for the benefit of society? Can the hierarchical approach, based on synergistic/competing intelligent agents using layered subsystems of intelligent supervisors providing command level directives for conventional controllers, yield solutions to some of the pressing problems in the field? We believe that such hybrid systems, which can make best use of existing as well as new knowledge about the process, will open up new horizons and lead to even further developments. Our challenge is to find practical solutions to the complex problems faced by society in the control of agriculture and the environment.

*The demand of building Digital Earth*
To develop Digital Agriculture is also the demand of Digital Earth, (1998). Digital Earth is inseparable from sustainable development strategy and is its important content. As a multi-resolution, real three-dimensional system, Digital Earth has great application potential in politics, economy, military, and many other fields. The building of Digital Earth is huge system engineering, involve mass data, and need the cooperation of governments, institutions, enterprises and technologists to finish it. Agriculture is an important constituent part and service target of Digital Earth. The construction of Digital Agriculture can make agriculture connect with Digital Earth early, and under the direction of unified ideology of Digital Earth, realize the share of resource and information between agriculture and other departments. Digital Agriculture can perfect the building of Digital Earth and fully utilize the finished outcome of the Digital Earth.

The Demand of Resource and Information Sharing

Resource and information sharing is the basic character of digitalization of the Digital Agriculture. Many countries have engaged lots of people, material, and money in the study of agriculture modernization. Digital Agriculture rationally programs the overall object and frame of agricultural development. According to that object and frame, it is possible to make an overall planning of the capital construction of farmland, the construction of agriculture information system and to develop agricultural machinery to mobilize the activity of processes to avoid the waste of resources.

Practice of Digital Agriculture

Agricultural information databases have been developing quickly. The contents of databases involve soil, meteorology, climate, cultivation system and many other aspects related to agricultural production. Other organizations, such as geography, geology, hydrology, meteorology provide necessary data for Digital Agriculture. Many growth simulating models for wheat, rice, cotton, etc. have been built. The application of GIS and GPS is more and more popular in the monitoring of crop growth, soil moisture content, flood and drought, disease and insect damage. Meanwhile, agricultural expert systems have involved all the fields of agriculture. The development of aerial and ground based remote sensing technology and the improvement of spatial position precision have made it possible to construct a spatial and temporal observation networks to collect the real-time information.

The Development of Digital Agricultural Machinery

Significant progress has been made on the aspects of object recognition and automatic drive mechanism in agricultural machinery. Digitized machines for soil fertilization, sowing, picking and pruning have come out. Digitally controlled agricultural machinery can reach the level of human driving. From the viewpoint of technique, digitized agricultural machinery can satisfy the demands of Digital Agriculture. The key problem at present is how to put all the parts of Digital Agriculture together, and let them work harmoniously for advantages of the whole system.

Strategies to develop Digital Agriculture

The Digital Agriculture should be carried out in a planned way under the direction, participation and cooperation of governments, industrial sectors, and scientific research institutions. At present it is needed to make overall plans, to strengthen the construction of agricultural information infrastructure to reinforce the study of key technologies in Digital Agriculture and to build test bases for Digital Agriculture. Digital Agriculture shows a beautiful prospect for us. It will liberate agricultural productive force greatly, change the mode of production and realize a qualitative leap of agricultural activity.

Japanese Case Study

This section describes some findings of agricultural research studies being conducted in Japan in three areas: 1) artificial intelligence (AI) or computational intelligence applications in agriculture and the environment, 2) intelligent environment control for plant production systems, and 3) intelligent robots in agriculture (Hashimoto et al., 2001). Researchers in Japan are now integrating the new technologies for autonomous navigation in the field of bio-system-derived algorithms, finite element inverse technique using a photosynthetic algorithm, neural network training by a photosynthetic algorithm, decision system consisting of neural networks (NNs) and genetic algorithm (GA)s applied to the optimization of plant growth, the recent
developments of intelligent agricultural robots and the intelligent approaches for mechanizing complex agricultural system

**Computational Intelligence in Agriculture**

Many problems in agriculture involve optimizing different types of bio-systems, such as drainage and irrigation systems, crop scheduling, and the handling and blending of materials. The bio-systems depend on decision parameters that can be chosen by the system designer or operator. An inappropriate choice of decision parameters in testing and fitting of quantitative models causes serious flaws in performance, as measured by some objective or cost function. Scientific research in any problem area consists of an iterative process of building explanatory or descriptive models, collecting data, testing the models, modifying the models when discrepancies are found, and then repeating the process until the problem is solved satisfactorily. The problems that deal with optimizing bio-systems and fitting quantitative models eventually require refinement or processing using adaptive search procedures or optimization techniques. There are many search techniques, including calculus-based techniques (gradient methods), knowledge-based techniques (heuristic methods), stochastic techniques, and biologically inspired algorithms (genetic algorithms). Photosynthesis is one of the most important biochemical phenomena and can be viewed as a natural implementation of an optimization. It is sometimes mentioned that a plant is not optimized by nature to function as an energy conversion device due to its low energy conversion efficiency of about 3%. Plants are under heavy functional constraints to maintain the diverse set of biological activities necessary for their survival and for the preservation of their species. The bio-system-derived optimization algorithms contribute to control applications by providing additional search technique options.

**Design of a Control System for Bio-system Optimization**

The plant roots in the deep hydroponic system always immerse into the nutrient solution. The nutrient concentration of the solution is automatically adjusted to the appropriate set point by mixing the highly concentrated nutrient solution and water. For growth optimization of plants in plant factories, optimal control of the environment is essential and requires taking the physiological status of the plant into consideration. A decision system, which consists of NNs and GAs, determines the optimal set points of the environment on the basis of plant growth data. In this method, plant responses affected by environmental factors are first identified using NNs, and then the optimal environmental set points are searched for through simulation of the identified NN model using GAs. The Japanese study found that the time variation in the physiological dynamics of the plant, along with the growth, could be captured by using a recurrent identification and search technique to determine the optimal values. That is, the identification of plant responses and the search for optimal values are periodically repeated to follow changes in the physiological dynamics of the plants. The optimal value can be changed according to the change in the physiological status of the plant.

**Neural Networks**

In the study, NNs were used for creating black-box models for simulation, which predict the nutrient concentration of the solution. For dynamic identification, arbitrary feedback loops that produce time histories of the data are necessary elements of the network. The data samples are divided into two data sets: a training data set and a testing data set. The former is used for training the NN, and the latter for evaluating the accuracy of the identified model. This type of model validation is called “cross validation.” The system order and number of the hidden neurons in the NN were determined based on cross validation.

**Genetic Algorithms**

To employ GAs, an “individual” for genetic evolution must first be identified which is an indicator for measuring an individual’s survival quality. All individuals are evaluated based on their fitness values. During the evolution process, individuals having higher fitness reproduce and individuals with lower fitness die in each generation. An individual having the maximum fitness is regarded as an optimal solution. The procedure of the GA (Goldberg, 1989) employed is as follows.

- Step 1: An initial population consisting of several individuals is generated at random.
• Step 2: Several individuals in another population are added to the original population to maintain diversity.
• Step 3: Crossover and mutation operations are applied to the individuals selected at random.
• Step 4: The fitness values of all individuals are calculated using the NN model, and their performances are evaluated.
• Step 5: Superior individuals are selected and retained for the next generation (Selection).
• Step 6: Steps 2 through 5 are repeated until an arbitrary condition is satisfied.

An elitist strategy was used for selection (i.e., the best individual in a generation was carried through to the next generation).

Measurement and Identification

First, the data for identification were obtained. The daily changes in data sets observed for plants grown in hydroponics, as well as the light intensity and nutrient concentration of the solution during the seedling stage. The control period is restricted to the seedling stage. Three or more data sets are necessary for identification. These data were measured every day using an image-processing unit. The response of the data sets to both nutrient concentration and light intensity was then identified by an NN (Narendra and Parthasarathy, 1990), and a black-box model was created for predicting the growth pattern.

Optimal Set Points of Nutrient Concentration

It may be noted that there is no guarantee that GAs yield a global optimal solution. In the case study in Japan an optimal value obtained from a GA was confirmed by using a round-robin algorithm that systematically searches for all possible values around the optimal solution at the proper step. An optimal solution was also confirmed with a different initial population and different methods of crossover and mutation. In hydroponics, as mentioned above, since the roots of plants are always in a suitable environment for the uptake of nutrient ions, vegetative growth during the seedling stage is easy to promote. Active vegetative growth during the seedling stage will result in poor reproductive growth in the future. The vegetative growth must be suppressed at the early seedling stage, before the flowering of the first truss. The low nutrient concentration seems to be effective in suppressing excessive vegetative growth during the seedling stage. The high nutrient concentrations in the later steps appear to be useful in accelerating reproductive growth (i.e., the flowering of the trusses and the fruit setting of during the seedling stage).

The conventional control strategy is to increase the nutrient concentration in a stepwise fashion with the growth of the plants. With the optimal control the stem growth was significantly suppressed by the low nutrient concentration at the early stage, whereas the leaf growth did not vary significantly. Thus, the effectiveness of this control system was also confirmed experimentally.

Intelligent Robots in Agriculture

In Japan, agricultural robotic research is widely performed in the areas of autonomous navigation, harvesting, and nursery production. Research in autonomous navigation is being conducted in universities, in government institutes, and by agricultural machinery manufacturers. In universities, due to financial limitations, most of the research has focused on methodologies such as navigation, sensing, and the application of control theory. At research institutes and manufacturers, which have more financial resources, more practical systems were developed. Research in harvesting robots is performed mainly in universities. Nursery robots are developed mainly by government research institutes and manufacturers, and some of them are reaching the market. In particular, grafted nurseries, such as cucumber, watermelon, tomato, and eggplant, are widely used in greenhouses, and various types of grafting robots are being developed by agricultural manufacturers and other types of industry (Chiang and Safonov, 1992).

Autonomous Navigation

At the University of Tokyo, a machine vision algorithm for crops was developed and applied to vision-guided navigation of a tractor, which would be used for row crop husbandry such as mechanical weeding and precise chemical applications. For vision guidance, image analysis of the crop field is essential. Thus, highly accurate discrimination of crop area from the surrounding soil area, detection of boundary lines between crop and soil areas, and position identification using a three-dimensional perspective view transformation are required. Discrimination of crop area was performed using color transformation of an HSI (hue, saturation, and
intensity) transform. Discrimination between the crop canopy and soil area was successful using the HSI transfer without the influence of climate and shooting time. A least-squares method was used for boundary detection between crop row and soil area, and a three-dimensional perspective view transformation was used for position identification.

Work is continuing on this project to increase the speed, and work on vision guidance in the paddy field is in progress. At Hokkaido University, an NN vehicle controller was designed in which the motion of a mobile agricultural robot was specified as a nonlinear system with high learning ability. At Kyoto University, an automatic “follow-up vehicle,” using two small head-feeding combines was developed. A human operator in the front vehicle controls it, and the follow-up vehicle is automatically controlled by computer. At Ehime University, a small automatic transport vehicle equipped with a carriage self-correction mechanism was developed for use in greenhouses (Yamashita et al., 1991) In 1993, the Japanese Ministry of Agriculture, Forestry, and Fisheries (MAFF, http://www.maff.go.jp) initiated the Agricultural Machine Development Project in which the development of un-mechanized machinery was promoted. Development of a tillage robot and driverless air blast sprayer were started in BRAIN (Bio-oriented Technology Research Advancement Institute), and a driverless air blast sprayer has been in field use. Through this project, many technologies have been developed, and a total station with automatic tracking for moving objects is now being used as the position sensor of a tillage robot in the field. The automatic tracking, position measurement, and data communication performances were sufficient at a distance of 500 m. The tillage work was completed within 2 hours and 15 minutes at a speed of 0.45 m/s. The work area was 50 100 m². A self-diagnosis function and an alarm function are also incorporated. At the National Agricultural Research Center (NARC, http://ss.narc.go.jp/) at Tsukuba, Inoue applied a differential global positioning system (DGPS) and an optical fiber gyroscope (three axis) mounted on a 55-kW (75-HP) tractor for tillage, and a Kalman filter was used for estimation of the current position. The accuracy of the DGPS was 0.15 m (sampling speed: 1 Hz), and that of the optical fiber gyroscope was 0.3°. A rotary tillage test was performed in the field at a speed of 1m/s. Nagasaki University used a real-time kinematics GPS (RTKGPS) with an optical fiber gyro for an autonomous rice planter. As the GPS data has a delay time (about 0.2 s) caused by communication with the reference, compensation for this delay was added for real-time position estimation. The GPS antenna was mounted on top of the vehicle, resulting in an error of 0.1 m at a roll angle of 3°. This inclination was also corrected. Steering angle was determined according to the difference in attitude angle error. At the National Grassland Research Institute (NGRI, http://ss.ngri.affrc.go.jp/), an autonomous tractor for forage production was developed using a fiber-optic gyroscope and an ultrasonic Doppler speed sensor for position identification. Application of a tracking laser finder system and laser range sensor on automatic farm machine systems has been performed for an autonomous rice planter.

Harvesting Robots

Developments of harvesting robots were conducted in the United States, Europe, and Japan in the 1980s. In Japan, research on a harvesting robot for tomato was initiated in 1984 at Kyoto University. Since 1990, Okayama University has been leading the research in harvesting robots, such as for tomato, cucumber, grape, and strawberry crops. In these robots, spectral reflectance was used for the discrimination of fruit from leaf and stem. The reflectance of the fruit is higher than that of leaf and stem in the near-infrared band; therefore, band-pass filters of 550 and 850 nm were used with a monochrome camera for the recognition of fruit. In this research, the cultivation types were also improved to discriminate the fruit from other parts. A redundant manipulator is used for the harvesting to avoid obstacles such as stems or leaves. Robots for harvesting leaf vegetables such as cabbage are also being developed. However robotic performance is still low and the human operator is superior in cost and reliability. Therefore, even in Japan, continued interest will depend on new technological innovations.

Nursery Production Robots

Nursery production robots such as transplanting and grafting robots are widely used. In Japan, the grafted nursery, which has strong tolerance against injury by continuous cropping, is mainly used in the greenhouse. Although there is some variety in grafting methods, for the most part, the machines put together a scion and a rootstock using a clip, pin, and special bond adhesive method. Proper treatment after grafting is a necessity, typically requiring a dark chamber with high humidity; thus, an increase in the success rate is required. Grafting machines operate on the plants one by one or in one row at a time. The performance of the grafting machine is about 800-1,000 plants/hour, which is ten times that of human operators. Plug-type seedlings are transplanted from a small tray, in which seedlings are planted at higher density, to a larger tray, and some
plants are transplanted into separate pots. A transplanting machine is used for this operation. Its performance is approximately 6,000 plants/hour. Sensing of the stem is critical in this operation, and photo sensors or capacitance sensors are mainly used. Several types of these machines are already on the market. Although research in tissue culture robots was performed in the early 1990s in the United States, Europe, and Japan, the market for this machine was too small.

**Networks in Digital Agriculture**

To make use of the machines in digital agriculture in an efficient way high level information must be taken into account from different areas of the surroundings in the broadest sense. The application of this information for production planning and the production process itself will increasingly be done with the help of network systems. An extensive network of agricultural institutions already exists (including agricultural software suppliers, machinery industry, administration, and public agricultural information services. These well-established services also make use of existing data networks such as the Internet. For production management at the farm level, data must be exchanged between production planning (mostly stationary) and production facilities (stationary and/or mobile). Within the production facilities, data are also transmitted for control purposes. Here, completely different conditions must be met with regard to the amount and time scale of data communication. These conditions cannot be fulfilled by global networks such as the Internet. Therefore, in this area, completely different data transmission techniques must be used. Complex electronic control systems can only operate efficiently if their various components are able to exchange data automatically. To ensure compatible data exchange between different types of farm equipment from different manufacturers, standardized data communication systems need to be installed. At present, the development and design of farm-specific data networks have made greatest progress in the area of plant production. These networks mainly serve to exchange process data, which are necessary for technical control, to inform the operator, and to exchange data with stationary farm computers.

**Fig. 1:** Agriculture embedded into its environment with various influences and effects

(Source: Adapted from the special issue on “Computational Intelligence in Crop Production,” R.E. King and N. Sigrimis, Guest Eds., *Computers and Electronics in Agriculture*, vol. 31, no. 1, 2001)

Modern machines and implements are controlled by electronic control units (ECUs). These ECUs are coupled by a network. This network additionally includes a human-machine interface (User Station) and a computer interface between the mobile and stationary system areas (Task Controller). Tractors, Machinery for Agriculture and Forestry—Serial Control and Communication Network provide open interconnection systems for on-board electronic systems. The main purpose of the network is to standardize data transmission between different machines or parts of machines (tractor to implement, tractor and implement to user station, tractor and implement to farm computer, etc (Munack et al., 1999). In designing networks, several fundamental requirements and preconditions must be considered.

- The network is anticipated as a basis for setting up and running distributed process control systems (e.g.,
control of the distribution of fertilizer, application of pesticides, irrigation). For these tasks, the network must exchange data between technical components of the agricultural machines with low time delay.

• Production processes are often performed by combinations of machines and implements that are manufactured by different international companies. This calls for a standardized network.

• In such combinations, implements are changed frequently, which causes multiple connections and disconnections at the physical bus line. Therefore, a serial bus with simple connectors and cables is preferred.

• The changing of implements always alters network configuration. To avoid additional workload for the operator and the need for a special computer to do network administration, the entire network must be able to monitor, control, and reconfigure itself automatically.

• The network must allow the operator to monitor and control the machinery combination.

• For automated information-based farming, such as precision farming using field operation maps with position-specific set points, data must be available. These data are prepared on the stationary farm computer during production planning. Conversely, measured values such as soil parameters, yield data, and the like, collected during field operation, have to be transmitted to the farm computer as a basis for later production planning. This can only be done by using machine-readable data storage and exchange.

Agriculture requires the application of field machinery capable of precise, repeatable operations based on models of systems processes. Such equipment requires a host of high-precision sensors and actuators. Most performance specifications for machinery systems used in precision agriculture can be met through the sequential design of the mechanism, the controllers, and the information systems. In the mechatronic design process outlined in this article, the efficiency of the design process and the performance of the mechanisms can be improved considerably or even be optimized through concurrent, integrated development of the mechanisms, control systems, and advanced information systems. Such advanced sensing systems with modern feedback controllers can generate significant demands for data processing and require substantial communications bandwidth. Standardized agricultural bus systems form the backbone for the high-variability and high-bandwidth data streams.

Conclusion

The world is in transition to one in which there will be more people, greater consumption of materials and resources, more global interdependence, and a need to reduce poverty without destroying the environment. Over the past two decades, Sustainable Development has become a principal concept in integrating technological, economic, social, and political issues to decide environmental protection and economic development. The future depends on harnessing the power of modern technologies, consistent with the interests of the poor and hungry, and with respect for the environment. Agriculture, as a source for food, natural raw materials for bio-industries, and energy, will increasingly be a major driver of this transition. Sustainable Development is a “process” of redirection, reorientation, and reallocation—an evolving process rather than a static definition. It depends on a fundamental redesign of technological, economic, and sociological processes to effect changes. To get beyond the various images of Sustainable Development, there is a need to develop a “science” of sustainability and systems of implementation. This leads to suggest that the process of transition to a sustainable world will include:

• Streamlining processes and reusing materials with a goal of zero waste.

• Embracing new technologies of information science, biotechnology (genomics and integrative molecular biology),

• and advanced materials to reduce environmental problems while increasing economic productivity.

• Utilizing renewable resources for energy to reduce or eliminate our dependence on fossil fuels.

• Developing sustainable communities based on the efficient use of space, increased conservation of materials and energy resources, and reduced transportation.

• Improving community livability and developing more efficient administrative and planning processes to demonstrate ecological living that is economically and socially desirable.

• Developing sustainable agriculture as a principal component of sustainable communities where use of fossil fuels, insecticides, herbicides, and inorganic fertilizers is minimized or eliminated.

• Focusing on newer and innovative sustainable enterprises such as bio-based industrial products.

The challenge is to rethink how the material needs of society can be met by using agriculturally based
systems. This rethinking involves an integration of science and engineering with an emphasis on ecological processes and socioeconomic phenomena. Technologies such as biotechnologies, information systems, and control and management systems will play a key role in inventing new processes and ensuring their effective and efficient execution at the highest possible quality and lowest cost.

Communications networking of production units has become an important feature of agricultural production processes and can be expected to continue to grow. Farm operations can communicate with weather services, traders, contractors, suppliers, biological services, consultants, and many other organizations. In these applications, the Internet already plays a key role. For on-farm communication, which is mainly used for online or inline applications on or among tractors and implements, a specific communication system, the agricultural bus system has been developed. This consistent communication system serves as the strength for precision agriculture, as demonstrated by the examples in this study.

As a case study the application of intelligent approaches to optimization problems in agriculture in Japan has been discussed. New algorithms were applied to search and optimization problems in bio-systems. An intelligent control system consisting of a decision system based on NNs and GAs and a feedback control system were applied to the optimization of the growth of hydroponic plants during the seedling stage. The optimal controllers for nutrient concentration were Recent developments in intelligent agricultural robots in Japan were introduced. There is great demand for robotics and automation for crop management tasks, such as pesticide and herbicide application; thus, autonomous navigation in the field is a promising research area. A robotic system combining machine vision appears to hold the most promise for the future. The nursery production robot, transplanting robot, and grafting robot are already in the marketplace, and many new technologies and innovations are being developed in this area.

References


