Aus dem Institut für Biosystemtechnik

Nick Sigrimis
Yasushi Hashimoto
Axel Munack
Josse DeBaerdemaeker

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Prospects in Agricultural Engineering in the Information Age

-Technological Developments for the Producer and the Consumer

Nick Sigrimis, Professor
A.U. of Athens, Dept of Ag. Engineering
Iera odos 75, Athen 118 55, Greece
n.sigrimis@computer.org

Yasushi Hashimoto, Professor
Ehime University, Dept of Biomechanical Systems
Tarumi, Matsuyama, 790, Japan
YasushiHASHIMOTO@agr.ehime-u.ac.jp

Axel Munack, Professor
Institute of Biosystems Engineering,
Federal Agricultural Research Centre (FAL)
Bundesallee 50, D - 38116 Braunschweig, Germany
MUNACK@kepler.dv.fal.de

Josse De Baerdemaeker, Professor
K.U. Leuven, Dept of Agro-Engineering and - Economics
Kardinaal Mercierlaan 92, B-3001 Heverlee, Belgium
Josse.Debaerdemaeker@agr.kuleuven.ac.be

Abstract:

This paper has been motivated by the advances in the field of Information Technologies and cites recent applications in solving engineering problems in Agriculture. Applications examples from authors' research and development are presented in short and future speculations are connoted. Even with the limited number of application areas treated in this contribution, it is clear that in the future a strong interaction between biology and engineering will form the solid base for interesting developments. IT is the enabling technology for both the scientist and the farmer, in the laboratory and in the farm.

Keywords: Management, Control, DSS, Networks, AI, Precision Agriculture

Introduction

In today's world, nearly every aspect of our lives depends on computers. The list includes communications, finance, health care, education, commerce, transportation, security and even entertainment and safety (e.g. automobile braking systems). Like the shift from steam to electricity, the shift from motors to information will dramatically alter the means of production in the next decade. Products have become cheaper and better because of computerized factories, electronic purchasing and optimized management. In fact, IT is most beneficial when it serves the bottom line. Agriculture is affected and is building its computerized plant and animal factories as well as precision farming systems. We live in revolutionary times. Until about 1984, industries invested most of their capital in machinery. In the mid-1980s, the amount spent on machinery was overtaken by the amount spent on computers. The definition used for IT-market is: "spending by businesses, homes, government, and education on IT hardware, software, and services". The European Information Technology Observatory (EITO) and other organizations have added telecommunications making it essentially ICT (Information and Communication Technology). Agriculture is thought by some as the growing giant consumer of ICT and electronic technologies. Soon it will be poised to reap the benefits of these investments.

Current developments in agricultural technology serve to improve the production processes or specific implements and means of production. The objective is to reduce the consumption of agricultural supplies and to raise the quality of the implemented processes. Deciding elements for further developments are: laws, regulations and standards on the national and international level as well as technical innovations in agricultural and other fields of research (see Fig. 1).

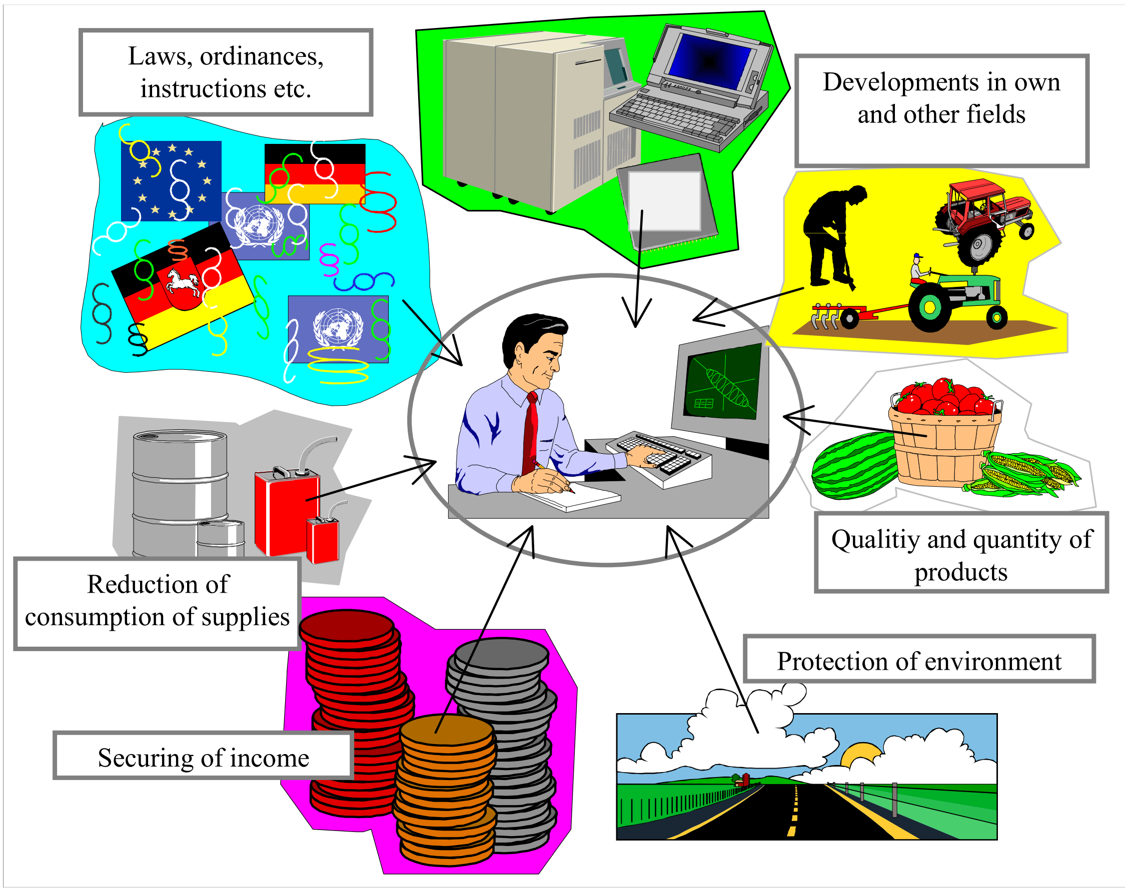

Fig. 1: The driving forces for agricultural development (source: H. Speckmann-FAL).

In the following, some of the future developments in agrotechnology that can address the foreseen needs are described. This description is based on ongoing research found in the current literature, research proposals and personal contacts. It is obviously incomplete and clearly reflects the authors' interests.

Automated farming is as difficult an engineering problem as automated manufacturing. With the additional hard constraint of restricted profit margins, it cannot tolerate low returns on new investments or long break-even-times. The trend in Agriculture is clear: the consumer wants "cheaper and better products" as influenced by other industrial products, including information products. The solution is felt, sometimes hard for the people; reduce cost by aggregation, much like the industry merges. Agriculture is restructuring and will need new machines, new farming methods, and a more human-friendly environment. Competitive advantages will be needed for survival. This is the new role of the engineer for Agriculture in the information age. A new reality is coming. The horizontal production (profit/acre) is losing anyway. A way to increase agricultural income is to increase vertical production, that is the value of the products which society is willing to pay more for (e.g. the natural aroma, biological products, health products, etc). The new farmer will need new machines and completely integrated information systems and spend his time interacting on high management decisions and not on how to make subsystems work together. New friendly machines and cooperative information systems do go along with biological production, the chemicals don't.

Precision Agriculture

Precision Agriculture, as the term is used today, is the application of information technologies, GPS and GIS to the management of farms. The goal of Precision Agriculture is to improve the efficiency of operations and the quality and consistency of agricultural products by compensating for the spatial variability of the soil environment.

This type of definition includes only the application of information technologies in the horizontal coordinates and excludes the vertical dimension. Optimal management of agricultural inputs for processes without spatial variability (animal husbandry, greenhouses etc) or on the average of field characteristics, has been the focus of research for more than 20 years. For example, hydroponic methods enable very precise management of water and nutrients supply. Thus the term is not new if we do not wish to exclude developments used for precise decisions (i.e. animal individual management systems and computerized feeders, economically optimum heating set-point tuning for greenhouses etc). It would be unfair to exclude this work and remain with "imprecise agriculture" for all these years, until GPS was invented. Therefore the truth is that the invention of GPS and the proliferation of electronics and Georaphical Information Systems (GIS) made it possible to start thinking of extending the term of precision in the spatial coordinates as well. It is better then to use the term "Precision Farming" when we mean the management of spatial diversity of fields. Josse De Baerdemaeker (1995) has used the term of "site-specific farming" instead.

Briefly, Precision Farming allows us to record data with reference to a coordinate system (much as we have done in a milking parlor with reference to an individual animal). Then for each identified spatial class we will have to apply all the optimizing management tools we have developed over the years to make an adjusted per "site" decision. Precision Agriculture (including precision farming) depends on i) precise monitoring of the process (sensors on temperature, images, quantity, quality, coordinates of individual plants or animals etc), ii) estimating the end result with a (biological production) model and iii) computational tools to simulate and evaluate different scenaria, seeking a decision or a control estimate that will maximize efficiency or profit. When the optimal decision is made it is yet a matter of possessing the required precision machines or smart actuators to allow realization of the decision made. Therefore in order to apply Precision Agriculture it is necessary to depend strongly on Electronics, Information Technologies and Communications, and evidently it takes a highly trained and skilled manager to use these technologies effectively. For these reasons the above fields will be reviewed in the following.

I. Electronics Technology

This technology is present in all aspects of modern advances in industry, business and even home appliances as a standalone technology or as a vehicle information systems. The technology, in its many forms today, cannot be treated exhaustively here and we restrict ourselves to some landmark innovations in agriculture.

Specific advances, which have led to the development of special ASICS, started early in the 1970s with the need to identify moving animals remotely and passively (Sigrimis and Scott, 1985). These efforts to improve business profit margins by individual management gave several designs and several industry pick-ups. Today we have surpassed that objective and worldwide coding of animals is underway to improve consumer food safety by enabling trace-ability of the food chain. Another example in the ASIC era is the one developed for the TDR moisture sensor by IMAG Institute (Balendonk J.). Such developments, combined with the power of programmable ICs and smart sensor technology allow distributed monitoring systems for a complete coverage of field farms and of farming factories.

Future Sensors

MicroElectroMechanical Systems (MEMS) is the generic term for silicon micromachined systems integrating electronic circuitry with mechanical microsystems on a chip. Starting with relatively simple pressure sensors some 25 years ago, micromachined silicon structures have grown in complexity and sophistication. Today micromachined sensors and actuators are being applied in the medical, industrial, consumer, military, automotive and instrumentation fields. Tri-axial accelerator chips developed for automobile use, can be used in agricultural applications, monitoring of transportation of fresh fruit or estrus detection in animals (Gettens J. et al 1986). One significant achievement is the development of an instrument for measuring parts-per-billion of heavy metals in water. This instrument, which is roughly the size of a pen, is replacing traditional equipment weighing 30Kg and costing some $20,000. This miniaturization technology is promising bio-analytical sensors (biosensors) and instruments, which will allow on-line monitoring of agricultural processes, to increase food quality and safety for the consumer. The first MEM-CAD was developed at MIT but now at least three companies offer commercial MEM-CAD systems.

Other promising technologies are Ion Specific FET sensors (ISFETs), microwave sensors (i.e. bulk moisture), acoustic and other non-destructive sensors, and image technologies (light cameras, X-Rays, NMR).

II. Information Systems

Artificial Intelligence and Data Based Systems

It is almost impossible to present a comprehensive account of the technology, which is advancing so rapidly. They are today indispensable components of any information system. AI did not manage to gain mainstream status as expected but it is making considerable steps in embedded systems. Several of its soft-computing formalisms, such as Artificial Neural Networks (ANN) and fuzzy Knowledge Based Systems (f-KBS) are gaining wide acceptance in “user assistance”, “control” or “management” applications. The objective is to exploit the tolerance for imprecision and uncertainty in real-world problems to achieve tractability, robustness and low cost. Recently interest has grown to develop high-quality software of high efficiency and predictability. New programming methods are intentional, evolutionary, model-based and self-adaptive programming. Many of these terms have been borrowed from the world of control methodology (Laddaga R. 1999). According to DARPA “Self-adapting software evaluates its own behavior and changes behavior when the evaluation indicates that it is not accomplishing what is intended to do or when better functionality or performance is possible”.

Recent Advances in Agricultural Applications

Much effort has been invested in using soft-computing for agricultural applications. This trend is obvious because, by their very nature, agricultural problems are ill-defined and uncertain. Fuzzy systems and ANNs are the technologies mostly promoted today for control (Gates R. et

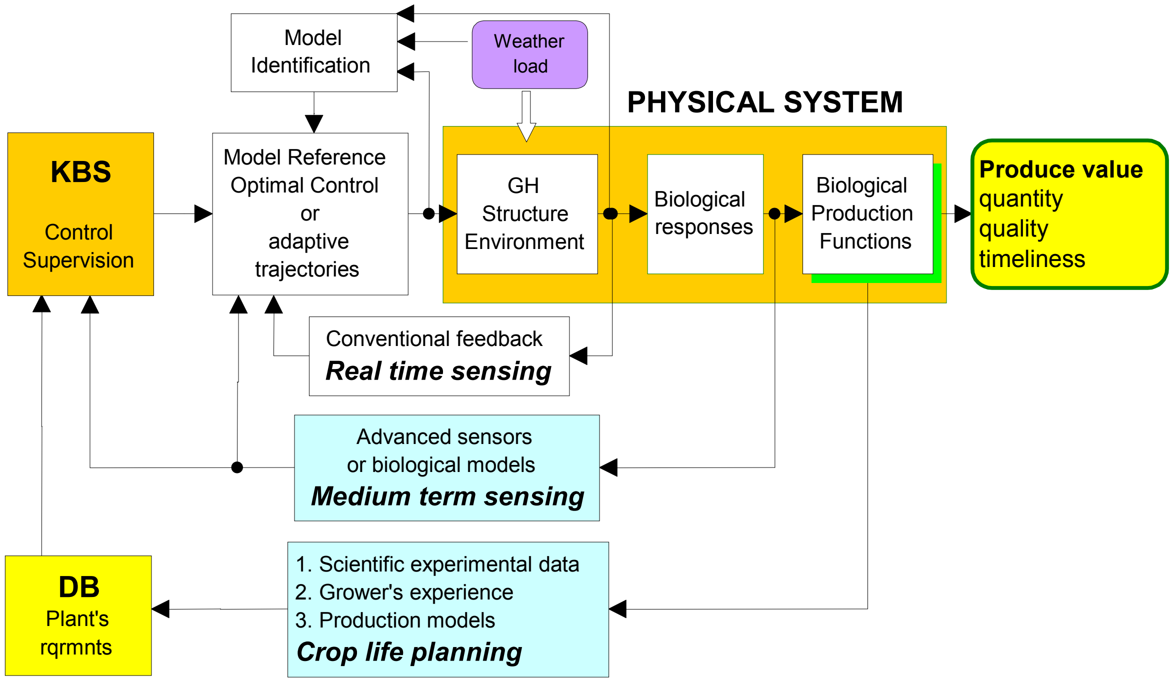

Figure 2: Multilevel control of the greenhouse environment as conceived in MACQU

al 1999) or decision support of process characterization (Charnomordic B. et al 1998) and farming operations (Girard N. 1998).

A recent development was MACQU (MAnagement and Control for QUality in greenhouses). The objective there was to improve product quality while minimizing the impact of greenhouse production systems on the environment. The system was implemented as a consequence of advances in our knowledge on plant bioresponses and modern management and control techniques (Jolliet and Bailey 1995, T.Gieling 1994, W. Paul - 1998, J.Garcia –1996, Sigrimis and Rerras -1996).

Within MACQU the overall process is organized as depicted in figure 2. This scheme provides a platform for an open system with functionality to implement all modern control techniques and management strategies. In the inner loop (fig. 2) GH physics, disturbance loads, plant' macro-environment as well as equipment variants, with their mode of operation and control methods (ON/OFF, PWM, disturbance compensated PID, etc) are met by using virtual variables and virtual control loops. This low-level control has been extensively studied in the agricultural control literature (i.e. Setiawan et al 1998, Gates et al 1999). In the medium term of sensing most recent activities investigate the use of advanced sensors (i.e. canopy temperature, imaging, CO2 assimilation, etc) or partial models (i.e. moisture relation to disease onset) to automatically adapt the operation or change of set-points or temporal change of objectives. The outer loop is where long time experience and crop-life planning uses "human" intervention to close the loop. Experimental or Empirical knowledge is used to set constraints or to edit fuzzy rules. This outer loop, in order to become autonomous, needs the existing knowledge, in the form of experimental conclusions or blue-prints, be transformed to a complete production model, appropriate for computer use. Some attempts in this direction, made by a number of researchers towards implementing model reference optimal control, have not given good acceptance results yet. It is a human natural reflection to hold high level decisions as these are the outcome of a combinatorial problem solving capability of the human mind, not well implemented yet by machines. One step taken by MACQU in this direction is to provide the operator with simulation capabilities where different management approaches can be tested and thus provide a decision support tool rather than a "human replica" in the outer loop. This facility, together with a decision fuzzy-KBS implementation tool (Anastasiou et al, 1998), builds a gradual shift where the machine overtakes from the lower level control loops to higher level management decisions.

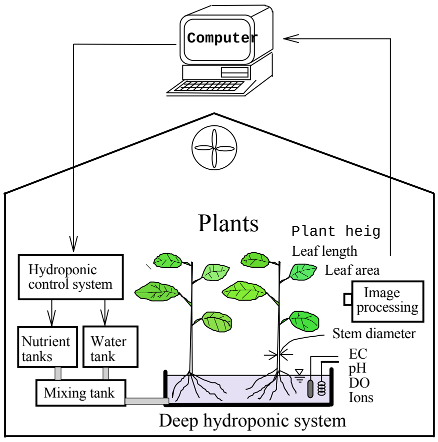

Fig 3 Hydroponic system control based on the SPA.

The MACQU system was designed as a general management program with real-time control capabilities and is configurable to manage biological production facilities. The system was furnished with special virtual variables for easy implementation of special control requirements for a greenhouse Climate (MACQU-C), for hydroponics (MACQU-H), for automating fisheries (MACQU-F), and for managing Irrigation of green-parks, highways etc (MACQU-Ir). A practical implementation of a perceptron was embedded in MACQU, as a transpiration estimator. It tuned irrigation in hydroponics systems (a system with long time delay) and has given excellent results in training speed and in accuracy of water management (Rerras N. et al 1998). A more detailed description of innovative tools implemented in MACQU can be found in Sigrimis N. 1999a and Sigrimis et al 2000.

The Speaking Plant Approach (SPA) and the Speaking Fruit Approach (SFA): In general, the physiological status of a plant during cultivation or storage varies with time and is affected significantly by environmental factors. For more effective control of such a system, it is efficient to monitor the physiological status of the plant continuously. Actually, measurement and identification of

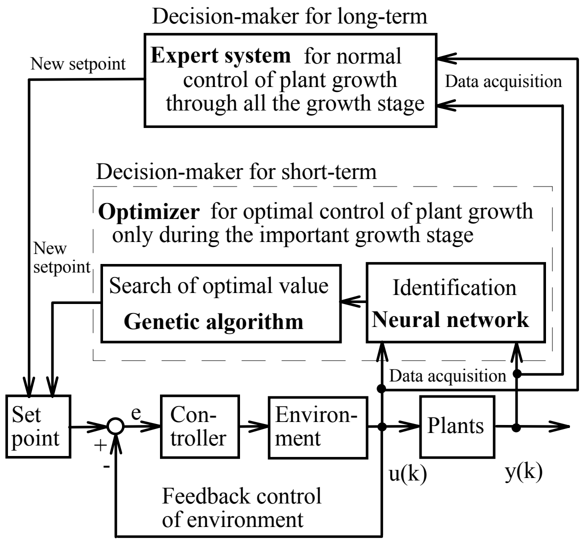

Fig 4 Hierarchical Intelligent control system composed of an Expert, a NN and a GA.

plant responses for optimal control of the environment, based on plant responses are necessary (Hashimoto, 1980). This is called "the speaking plant approach (SPA)" for plants during cultivation (Hashimoto, 1989; Tantau, 1993) and "the speaking fruit approach (SFA)" for fruit during storage (De Baerdemaeker and Hashimoto, 1994).

Paired optimization: Figure 3 shows a schematic of a deep Hydroponic system, where tomato plants are grown using the SPA concept. Plants are known to exhibit two types of growth: the vegetative and the reproductive. The first optimization problem is to determine the proper setpoints of the nutrient concentration in order to maintain a balance between the two types of growth for all the growth stages until harvest, using an expert system.

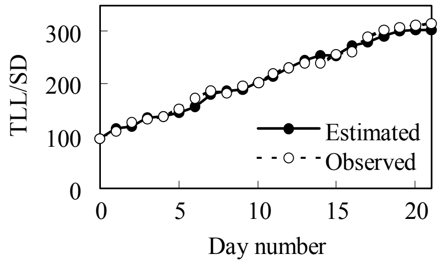

Fig.5. Comparison of estimated and observed responses of TLL/SD.

On the other hand, since the balance between the two types of growth is determined and fixed at the initial growth (seedling) stage, the optimal control during the initial growth stage is very important. For the second optimization problem, the initial growth stage was divided into four distinct periods: 1. the transplanting period, 2. the vegetative growth period after transplanting, 3. the flowering period of first truss, and 4. the periods of fruit set for the first truss and flowering for the second truss. The primary objective is to adjust the trajectory of the nutrient concentration along the four initial periods in order to suppress vegetative growth and promote reproductive growth. For the second optimization problem a NN plant response identifier was cascaded with a GA optimizer (Fig. 4).

Identification results: Fig 5 shows one of the identification results. It was found that the estimated responses are closely related to the observed responses. This result proves that a computational model could be obtained for predicting the behavior as affected by any combination of the 4-step setpoints of nutrient concentration.

Optimal control performance: The effectiveness of this hybrid system for the optimal control of plant growth was also confirmed by an actual experiment. Fig 6 shows superior performance of the proposed optimal GA approach compared to conventional approach.

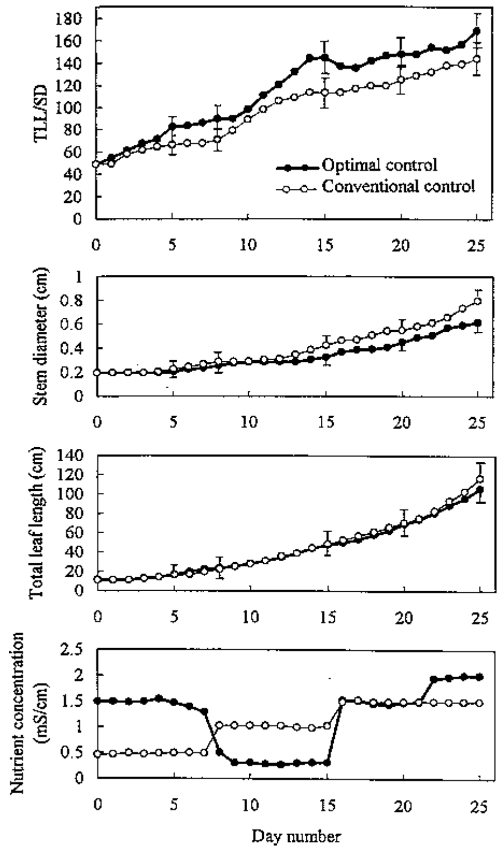

Fig. 6. Actual optimal control performance as affected by optimal 4-step setpoints of nutrient concentration.

Similar techniques have been developed for the SFA for fruit in storage (De Baerdemaeker, J and Hashimoto, Y. 1994, Morimoto, et al, 1997a). A more detailed description of the AI developments in Japan can be found in Morimoto and Hashimoto, 1999.

Agents for problem solving and control

How can we use Information Systems and make them more productive? How can Intelligent Systems be built for particular applications and how can they share their "experience" with other systems so as to be more robust and avoid pitfalls while benefiting from more global intelligence?

Traditionally, information systems consisted of databases, application programs and user interfaces. This practice is changing because the new demand is for open integrated architectures with a more global scope through cooperative action. The application domains, which drive the needs for new information services, are production (manufacturing and farming), electronic commerce, banking, training, education and environmental management.

Cooperative Information Systems (CIS) can be viewed as a collection of databases and agents. Knowledge bases, distributed systems and databases, have each matured enough and the greatest leverage for technological advance is expected from their integration into CIS. Databases can offer information sharing and AI techniques can offer data mining, multiagent systems, planning, scheduling and negotiation. "The world has a trillion dollars invested in Information Systems and they are not going to throw it away for next generation systems" (Michael Huhns, 1997). Consider a farm, which has an automated cow feeding system, an inventory on feed and supplies, data from its field precision farming machines, a crop management program and a grazing program. How, for example, could all these programs cooperate for enhanced enterprise management, and also intercommunicate with other twin farms of the same virtual community? or go one step further and place an order for concentrate feed with the supplier, when the feed stock is low? A promising approach to building such aggregations of components is the *information agent.*

New understanding of the complexity of natural systems was reported recently in Complex Adaptive Systems (CAS). Scientific reduction of complex phenomena at a higher level to simpler problems at a lower level is used (Wildberger, 1997). Systems in this new field of study share one common characteristic: adaptability. A complex system is considered to emerge from the interaction of multiple, autonomous, intelligent agents, competing and cooperating in the context of the overall system environment. In this view, a complex greenhouse system can be controlled by intelligent autonomous agents for optimum temperature, CO2, light, humidity, which can communicate and interact with each other in order to achieve optimum results. These systems can be seen to change, evolve or "learn" as their environment changes and as they come in contact with agents of other systems; for example the air humidity control agent in relation to the root environment operations agents or other physiologic or economic agents.

Although this technology has yet to create a well-defined programming paradigm and tools for less costly developments, some efforts to develop systems specifically for agriculture have been reported (Bouche R. and L. Ramdane 1998, Goggos and King 1999). For example two agents (one for the humidity and one for cost saving in a greenhouse) would bargain to resolve the situation of how ventilation must operate based on risk management.

III. Communications Systems-Networks

The enormous strides in digital technology and its applications have fundamentally changed the way information is generated, processed, stored and transported. This has moved our civilization from the Industrial to the Information Age. The Information Age is today dominated by the Network Age. Networking and communications will drive the revolution to its next level as we connect everything from offices and cars to tractors by some kind of Internet Protocol link. It is this linking of machines for information handling that is shaking society's very foundation. The trend is apparent: the wealth in each production sector will increasingly come from the connectedness of each particular economic activity. What kind of world will ubiquitous connectivity bring? One critical uncertainty relates to the pace of global and technological expansion. If these forces advance rapidly, a very different world results than one in which they advance slowly. How should these forces be promoted and supported in the world of Agriculture?

Broadcast TV signals already bring good pieces of information, including Internet, to the most remote farm, except with limited selectability and no interactivity (one way). Better use of wired bandwidth (telephone, ISDN, CATV) converts almost any existing connection from analog to a bidirectional digital connection and a medium with a plethora of multiservices and all desirable features of interactivity and selectability. And it is not very far when mobile communications will have no cost disadvantages and that will make possible for twinning (i.e. between Japan and Greece) not only at the farm level but even tractors while at work. And if they become intelligent, as it seems to happen, tractors can talk each other and share experience on doing their job (i.e. as a master of precision farming operations). Shall we allow the pace of progress be controlled by the general wave "players" or must we take an active part? Should we enhance the revolution at the farm level? Do we train farmers, from within these new media services, to take advantage of this revolution? What policies must be approved to extend the global network infrastructure to every remote farm? The power utility cable has reached every location. Likewise, the information cable (not just the telephone utility cable) should reach every location and if very remote then again using satellites. What does this mean for the present and future role of the supporting scientific societies? A farmhouse is not just a house but a small business, which needs to select and order the "inputs" and produce goods that may need immediate marketing.

The rapidly evolving information infrastructure will play a critical role in realizing the "global village" concept of the world. Farmers and agricultural producers must become active members of this "village". Satellite communications systems are essential in establishing the global information infrastructure (GII). The two big fixed networks, Internet and ATM, will be vastly strengthened by the bandwidth-on-demand capabilities of satellite networks.

Field Bus CAN

Recently we have seen activity on the development of an agricultural protocol. A working group of ISO TC23/SC19/WG1 is developing a standard (ISO 11783) based on CAN v2.0B which is faster than v2.0A and has a more expanded identification field of 29 bits.

There are no agricultural machines today equipped with ISO 11783 but there are many with a DIN standard. Changing of standards always creates a lot of problems and there are many manufacturers thinking which standard to follow. An interesting work is being proposed by H. Speckman (FAL) in order to make both protocols interoperable and save the machines that are in the field today.

<u>Motivation (purpose of the BUS)</u>

In many cases several working machines or agricultural implements perform the agricultural production processes. These machines and implements are equipped with electronic control units (ECU). For a co-operation of multiple ECUs an **exchange of data** (setpoint values, measured values, commands, etc.) is necessary. Compatible data transfer between agricultural machinery of different makers needs a **standardized open network**. Basic definitions for a network are the physical characteristics of the communication lines and the network protocol. The best is if a **commercially available network** is used, with an appropriate performance. It is the task of agricultural research and development to adapt such a network to the conditions of agricultural use.

At mobile systems implements are changing frequently and with it the network configurations. To add no work load to the operator (driver of the tractor) the network has to monitor, control and reconfigure itself automatically (**automatic network administration**). The **process data** (measurements, setpoints, commands, etc.) have to be exchanged between **arbitrary sources and destinations** with **small latency times**. For a high level management by the operator the network has to provide a suitable **man/machine interface**.

To improve the performance of mobile machine combinations for automated precision farming, data resulting from production planning (e.g. data of field operation maps) have to be transmitted from stationary computers to mobile machinery. Management information systems, which perform the necessary tasks, need the results of the production process on the field as basis for future production planning. This demands for a **standardized bi-directional data channel** between the mobile and stationary system areas.

To keep the agricultural network open for future tasks it should incorporate "place holders". Some of these possible future extensions are:

- a transparent data transmission between the stationary and mobile system area,
- a central resource to provide information about positions and movements on the agricultural field,
- a central resource for network system diagnosis, and
- resources for machine diagnoses.

State of Standardization in Germany

In the actual state there exist two standards, which fit the tasks of an agricultural data exchange. These are the German Standard DIN 9684 (standard for the agricultural BUS-System, LBS) and the International Standard ISO 11783. Both standards are based on the Controller Area Network (BOSCH CAN Specification Sept. 1991). CAN is an object-oriented network with random access and collision detection (CSMA/CD). DIN 9684 prescribes CAN protocol version 2.0A (11 bit identifier) which can define 2048 data objects with a transmission speed of 125Kbit/s. ISO 11783 uses CAN version 2.0B (29 bit identifier) with approximate 540 000 000 objects and 250Kbit/s. Both standards use the same physical layer. So it is possible to alter the transmission speed of DIN 9684 also to 250Kbit/s. The standards have different network management layers but with a small change in the ISO standard it is possible to operate both networks on the same BUS.

The two standards treat the network tasks very similarly, which is shown in Table 1. The network management layer (DIN part 3, ISO part 5) includes automatic initialization, system monitoring and treatment of conflicts and errors. The basic messages application layer (DIN part 3, ISO part 7) defines the treatment of cyclically transmitted basic data (e.g. ground speed, PTO speed). DIN defines 3 types of basic messages. In ISO an extended number is described. In DIN part 3 and ISO part 11 the process data are standardized.

The definition of the man/machine interface is placed in DIN part 4 and ISO part 6. This interface provides virtual user displays and input facilities for every ECU, which is active on the BUS. The ECUs construct the screen content with the help of resources. These resources are defined by the ECUs and loaded into the virtual terminal during system initialization. The operator can allocate the physical screen and input elements to the ECU of his choice.

The interface between stationary and mobile components is defined in DIN part 5 and ISO part 10. At the stationary computer this interface guarantees the bi-directional communication by standardizing data transfer files. At the mobile system area the data is passed by a task controller which translates the information into process data to control the relevant ECUs. Vice versa the task controller translates collected information from the ECUs into standardized data for the transfer files.

For these two interfaces DIN specifies the use of system resources, so called LBS Services. LBS Services are also intended for transparent data exchange, providing of position data, printing devices and diagnoses.

Additionally DIN allows the data exchange for special applications in the form of partner systems. Using partner systems the developer is not burdened to follow the data definitions of the standard. On the other side DIN has no special standard for a tractor ECU and the power shift application layer, which are defined in ISO part 8 and 9.

It is necessary that standards for agricultural networks have to be adapted and extended with the progress of development in agricultural machinery. To keep updates of existing systems efficient this should be possible only by changes in the implemented software.

Figure 7 shows a scheme of a tractor-implement combination equipped with an agricultural network according to DIN 9684 as an example of the use of this standard.

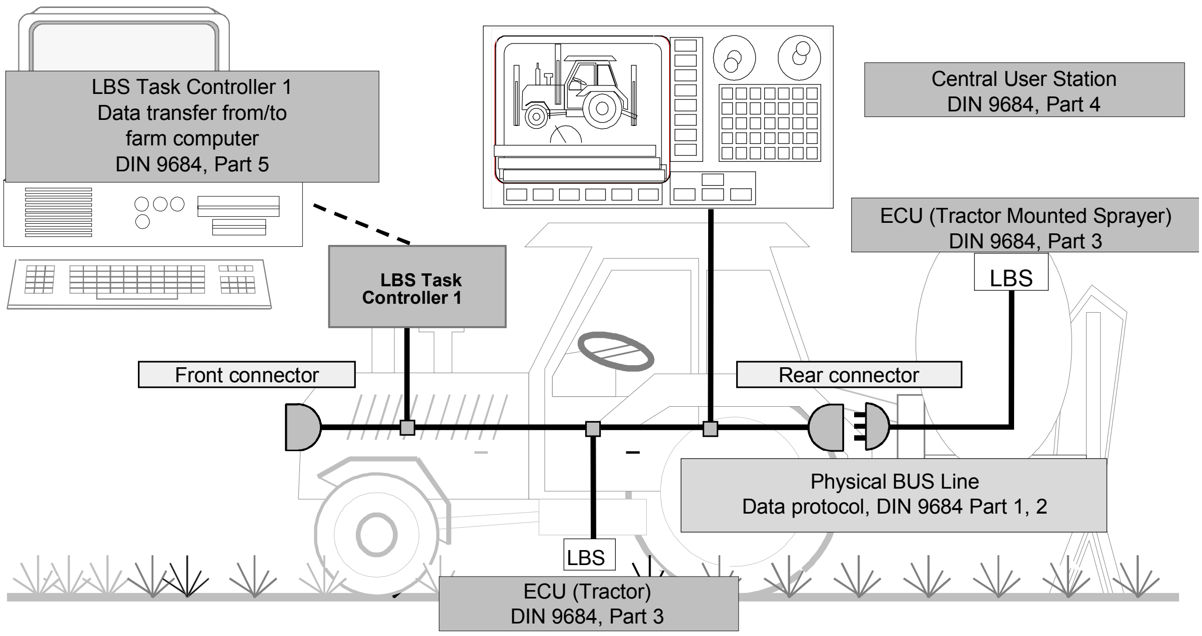

Fig 7: Scheme of a tractor-implement combination equipped with an LBS (source Speckman-FAL).

A resolution to this technical conflict must be given together with an agreed plan to a common solution. This solution should take into consideration that farm data may need to travel outside the farm through Internet. Farm Identification fields and other parameters could be added at the farm Internet connection node as well as other fields added by lower level protocols. For example in MACQU all information on the bus system is accessible by all connected stations (upto 256) as the normal mode of each is "listening". By a simple virtual definition at the very high programming level, issued by the central PC supervisor while "at work", any variable of any device can become a variable of another. The latency depends on the number of connected

Table 1: Comparison of parts of the standard in ISO 11783 and DIN 9684

Number	Title	Equivalence to LBS
ISO 11783 Part 1	Tractors, machinery for agriculture and forestry - serial control and communications data network - Part 1: General standard for Agriculture Mobile Data Communications	-
ISO 11783 Part 2	Part 2: Physical Layer	DIN 9684 Part 2 [1)]
ISO 11783 Part 3	Part 3: Data Link Layer	DIN 9684 Part 3 [2)]
ISO 11783 Part 4	Part 4: Network Layer for Agriculture Mobile Data Communications	DIN 9684 Part 2 and 3
ISO 11783 Part 5	Part 5: Network Management for Agriculture Mobile Data Communications	DIN 9684 Part 3
ISO 11783 Part 6	Part 6: Virtual Terminal	DIN 9684 Part 4 [3)]
ISO 11783 Part 7	Part 7: Basic Messages Application Layer	DIN 9684 Part 3
ISO 11783 Part 8	Part 8: Power Train Applications Layer	-
ISO 11783 Part 9	Part 9: Tractor ECU	
ISO 11783 Part 10	Part 10: Task Controller Application Layer	DIN 9684 Part 5 [4)]
ISO 11783 Part 11	Part 11: Mobile Agricultural Data Element Dictionary	DIN 9684 Part 3

[1)] DIN 9684 Part 2 Agricultural implement and tractors - Interface for signal transmission - Serial data BUS

[2)] DIN 9684 Part 3 Agricultural implement and tractors - Interface for signal transmission - System functions, Identifier

[3)] DIN 9684 Part 4 Agricultural implement and tractors - Interface for signal transmission - User station

[4)] DIN 9684 Part 5 Agricultural implement and tractors - Interface for signal transmission - Data exchange with the management information system, Task controller 1

stations, the BUS load, and can be several seconds. But the cycling sequence among the stations can be also defined depending on data priority. In example the weather station is usually connected to station1 and inserted in the cycling sequence several times. In this way a "neighbor's" variable can be used for decision-making and control in another's territory and so first level co-ordination among different units is achieved. The Central fuzzy KBS achieve further higher level co-ordination, for information or decision transfer.

Many protocol proposals have been tried over the years for particular agricultural applications (Hayson and Forward, 1995). It is of outmost importance that a generalized Open agricultural application protocol be drafted by ISO which will accommodate existing systems but also provide the flexibility and interoperability requirements of the future.

Precision Farming

Precision Farming has the potential to make a major contribution towards improving agricultural practice in order to reduce the impact on the environment from agrochemical wastage. Precision Farming is an innovation that encompasses many expensive IT technologies and most times it generates data stock. As Blackmore B. et al 1994 have noted, adoption of technology of sufficient capability to provide fully supported precision farming is likely to be an evolutionary process, with farms gradually improving their IT capability. Josse De Baerdemaeker (1995) has marked the following important areas for “site-specific farming”.

- *The information on soil variability*- Soil maps
- *Yield information* – Instrumented harvesters
- *The equipment location*- GPS-DGPS, lasers
- *The fertilizer treatment* - (weighing and dosing, uniform or controlled spreading)
- *Yield variations from one year to another* - Yields maps
- *The treatment of weed patches*-reduce chemicals
- *A crop response approach* – production models and speaking plants
- *Total quality assurance in crop production* – multi-source data collection, processing and management.

The technique, which the majority of the farmers find as carrying important information for better management, is the soil mapping, which however suffers from poor standards, possibilities for false information and cost. The encouraging fact today is that information technologies do cope with the advancement in video processing, data reduction and integration of multimedia databases with processing and decision-making programs. A promising perspective, as expressed by academia and farmers as well, is the satellite imagery techniques, which can solve the problem of providing good historical data and real time field monitoring.

The technology for site-specific farming or precision farming has been subject to rapid development during the last ten years. Initiated with high expectations some years ago we have not seen sufficient results yet, but some in environmental protection (smart sprayers) appears promising. However an assessment of its potential is required to identify promising applications within the larger field of Precision Agriculture and not precision farming alone, objectively pricing all benefits for the society and the farmer. Farmers in general indicate that the most significant benefits precision farming is expected to offer are financial and environmental, while traceability benefits are less important for them (Funtas S. 1998).

IV. The New Reality

e-commerce

In any discussion of the Internet's economic potential the numbers start flying to Billions and Trillions. Dizzying as the numbers may be, they all point in the same direction: **electronic**

commerce. Because commerce is global by definition, international organizations are active (ITU, ISO, EU, OECD etc). In June 98 a joint technical committee (ISO/IEC JTC1) produced a report on the standards needed for electronic commerce. Similar activities are underway in ISO/TC68/SC6, in IFIP-TC6.11 and in CEN. National and professional organizations and banking groups are contributing with their own specifications.

The effectiveness of e-commerce, compared to conventional purchasing process is best described by an example. Real-Time programming soft tools have been bought recently for Macqu program development using Internet search and a credit card. This has: a) eliminated the need for keeping a database of software vendors, b) made possible the selection of most suitable product based on most recent information from the world database, and c) zeroed the process (search-select-order-payment) delay from one month (as it did happen back only few years ago) to one day only!. Possibilities for productivity enhancement are great.

e-commerce will become the oil of the "frictionless" economy. Internet and/or private virtual networks provide end-to-end connectivity with the possibility of producer-consumer "direct marketing". The fast pace of expansion of this new reality makes any prediction insecure. Forrester Research (http:\www.forrester.com) predicts for '99 business-to-business e-commerce transactions a twofold increase, compared to 98, and a sixfold of business-to-consumer. The projection for e-commerce is to overpass the $1 trillion by the year 2003. These trends hold true with tremendous power for the agricultural market as well, under certain limitations which must be faced. Agriculture has a very diverse nature, many producers (farmers) and many consumers (all people), and non-standardized product quality. But it is for these reasons that if obstacles are removed the relative benefits can be tremendous for the producers and the consumers.

Remote Support

Close to e-commerce development comes e-support. Home connectivity brings, among other benefits, home remote operation and automation as well as remote e-support for home appliances of the future. The farmer, as a potential user of IT products in remote locations, will benefit the most from remote support. In Macqu for example, as well as in many other modern systems, it is possible to provide direct electronic support. This way a remote technical operator can do operation-logic setup according to "customer's specs-sheet", run diagnostics, fix problems by changing the setup, or even upgrade the software system. In this case when the local Macqu PC Station detects a remote connection request it switches the local Macqu

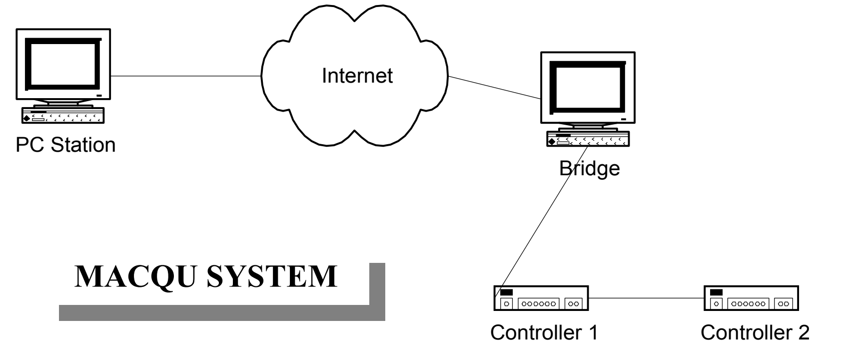

Fig. 8 Remote control case: The PC station is connected to the controllers via Internet

communication software to an IP bridge and gives control to the remote Macqu (Fig. 8), after level-access authorization checking. Further support is available for a camera connected to a Macqu controller to send images of greenhouse interior to the remote PC through Internet.

Inter-networking enables such features, which greatly enhance product value for the customer while reducing downtime, availability and reliability. With a small further step, distributed knowledge bases can be used to make high level decisions and management for the premises of connected members of future intranet VANs (Virtual Agricultural Networks).

The consumer side (quality and safety, biosensors)

Josse De Baerdemaeker (1995) has identified the following points that concern consumers of agricultural products:

I. Cultivation and crop protection measures

- *Sprayer inspection and boom vibrations* – improve performance (Ramon et al., 1995).
- *Weed and disease detection and control*- image analysis
- *Non-chemical weed control* - Mechanical hoeing, robotic transplanting (Okamoto et al., 1993).
- *Bio-engineering for crop protection* – pest resistance, genetic changes

II. Non-destructive testing in pre- and post-harvest operations

Fresh agricultural products must be picked at the right moment, carefully handled and sorted in order to meet customer requirements and quality standards.

- *The quality problem for the handling technology*- non-destructively mature harvesting.
- *Physiology, sensors and consumers* - X-ray, NMR, volatiles' detection, vibration and accoustic emission analysis, ultrasonic testing etc

With increased awareness of environmental pollution (i.e. dioxines) consumers are concerned about the safety of food products on the market. Consumer quality and health protection is of high priority today and a notable shift in research targets has appeared in most research programs. An upcoming technology promising much to be gained in this field is the immunosensors or biosensors technologies, which MEM technology can support for practical use. This sensor technology requires fusion of a bundle of disciplines as it includes biological reactions, advanced molecular engineering, chemometric or electrochemical transducers and detectors, and advanced data processing and estimation techniques (Sigrimis N. 1999b) to provide a useful indication.

The Remote Education Challenge

Applying the Web for educational purposes is a major field of research today. The dream of the "wired society" in which everybody and just about everything would be interconnected has driven several pilot projects such as fiber-to-home, interactive television, intelligent buildings and so on. However the real acceptance or the "available consumer budget" for these ideas are far below expectations. Tele-learning for a wide variety of educational scenarios has been perceived by many as the "killer app" (Finley M. R. 1999), that is, the application which could promote multimedia products such as videoconferencing systems. However this is an interdisciplinary subject and viable remote education applications will be those that will examine all factors involved educational, pedagogical, psychological, sociological and economical. Distant training does not only depend on technological issues but also on humanistic subjects such as formation of virtual communities, virtual schools etc. In order to gain high acceptability major consideration should be given to the usability and utility of the educational product. The user interface is a predominant design factor and should be *customizable* when users with very different characteristics are addressed.

Another education assisting technology we all use today is Digital Libraries. The Internet goes beyond providing the communications required for digital libraries. The Internet is turning into a global library itself, which you visit on your desktop and search using powerful tools to obtain information from allover the world. Digital libraries with agent based search engines can provide multimedia searching over heterogeneous libraries. The Digital Library Initiative (NSF-ARPA-NASA, 1994) has important implications for education (virtual universities and distance learning), information dissemination (virtual libraries) and information mining (content-based retrieval of images and video). It has become the driving application for Next Generation Internet and Internet 2, which promise backbones in excess of 10Gb/s and mechanisms for QoS.

While computer networks supply very powerful dissemination tools, tele-learning is the new method for educating people, and is expected to affect all sciences, Universities, Business education, and even people at home. Tele-learning can be realized in many different ways but has two very distinct modes: a) the synchronous (real time) course situation, which takes the form of a two-way networked distributed class, and b) the asynchronous case which can be realized via computer conferencing, voice/video-email or web tutorials (including captured course material). Courses and seminars will be available from any place in the world and competition will arise which will have a very beneficial effect on the quality of the offered material. Agriculture, and people serving it, has been always in the inferior position of getting continuous education due to its remote distribution and diverse characteristics. Now it is possible to avail very attractive training material for any subject, any level and for any place in the world. Therefore it is this community to take the most advantage of the new learning technologies and where we would expect the most substantial results to be seen. Social forces are also assisting the move in this direction.

The Role of Organizations

Changes in the interactions between technology, markets and regulations are on the way. The new technology will penetrate deeply into everybody’s life. What social obligation will different sectors of industry have to accept? If tomorrow’s world is to be IP dominated, how do we influence its development? Competition is everywhere and so do the educators will have to play with art to deliver competitive schools.

Certainly the service providers will reach the farmer’s house with their cable and service. But what is provided for farmer professional education? How can the farmer benefit from the technology in order to monitor and manage his land, and to do so in a modern manner, remotely? Agricultural organizations should take action to protect and improve the income of the farmer and advance his living environment. It is fairly safe to say that IT brings a notable shift to the “type” of investments and also the skill of labor and of scientists involved in services for Agriculture.

Agricultural Engineering societies are concerned with the role of IT in Agriculture and what is the right pace and type of technological advance such that Agriculture shares the same amount of benefits as any other production Industry. Agriculture does present limitations, due to wide spatial distribution of actors and activities but IT and connectivity have the power to bring uncountable economic and social benefits.

V. Conclusions

The incoming Information Society is widely seen as a brave new world where the full potential of information and communications services and applications is exploited for the social, cultural, and economic benefit of everybody. Concurrent engineering in biology, mechanics, electronics and other areas is the main cause for these developments. This type of work is a unique challenge for Agro-Engineering as it must deliver creative work based on knowledge of living and non-living material. IT technologies of GroupWare, simulation tools, design tools, and in field implementations are the enabling technologies to help the task.

As we approach the 21st century, we are aware of our ever-increasing reliance on computer-based systems. These systems, ranging from information systems to embedded systems, represent a crucial component of today's workplace. Agriculture is a big potential market for new technological products. In order to make successful inroads, the targets must include shares of benefits for the farmer, the consumer and lastly the technology developer and producer. There is great need for innovative applications and innovative solutions to enable effective "user-fruitful" applications. Our research and development must be "use-inspired". Discovery approaches by incremental improvements in productivity do pay off rapidly.

Scientific Organizations must take the lead and guide developments by setting priorities but also humanistic standards, regulations and legislation. It is likely that the steps in the agro-bio-technological evolution (better understanding of the biological processes and the properties of the biological materials) will also coincide with sudden technological developments in the field of electronics, computers, communication, materials science and machinery.

Our traditional understanding of training is too limited and must be modified to educate biological engineers who are competent to meet the changing needs of their employers and their profession. Farmer's professional training is also another key element; if not trained to be able to effectively operate the new technologies there is no way to succeed. And this training is feasible with the new information and communication technologies. This creates new ways of doing everyday work for both teachers and students and promises also a new workforce demand.

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