An Automated System for the Optimization of Production Processes in Agriculture

Y. A. Izmailov[1], Y. P. Lobachevskii[2], V. K. Horoshenkov[3]

All-Russia Research Institute for Agriculture Mechanization (VIM), 1 Institutskii Proezd, 109 428, Moscow, Russian Federation

Abstract: ***Technology automatization in agriculture enables us to solve efficiently problems associated with the population growth, sufficient food production and its quality. This applies through the whole chain of agricultural processes from the plantation of crop, fertilizing, harvesting, food storage, processing and distribution. The development of low-cost microcontroller technology and efficient control algorithms enables use to enhance the integration of agriculture processes, increase their efficiency and reduce losses. This paper reports on the development of a new SCADA control system which is designed to enhance the efficiency of seeding and harvesting processes. This system is integrated with the GPS so that the process is fully automated.***

Keywords: automatization, agriculture, informatics, microprocessor

1. Introduction

The use of automated information technologies based on modern electronic components and making use ofaccurate navigation systems, e.g. GPS or GLONASS enables mobile units, vehicles and stationary objects to optimize the performance of agricultural processes, increase the productivity, reduce the production costs and to improve the quality of the working conditions for the personnel involved in this work. Information technology management systems (ITMS) which have been developed in the last 30 year and are now being adopted by individual farms and large agricultural complexes are detailed in ref. [1-3]. An important benefit of these systems is that it addresses the issue of the limited capacity of a human operator to respond to a rapidly changing process (e.g. [4]). Agricultural processes often require intervention at the rate of higher than 1 Hz, which is commonly beyond the capability of a human operator. This suggest that it is advisable to adopt ITMS and those farms who do so are often called the intelligent farms. In our paper we propose new engineering solutions to improve further the quality of agricultural products, increase the labor productivity and to reduce the cost of the work.

2. Methodology

2.1. System Architecture

It is known that physiological barrier of a human operator to monitor and control systems through visual information is not less more than 1 sec, i.e. its maximum frequency is around 1 Hz. Therefore, in a short term a human operator is not able to control fast processes. The capacity of an information channel is:

$$y = x\log_2(1 + z_S / z_N), \quad (1)$$

where x is the Nyquist frequency, z_S is the mean power of the signal and z_N is the mean power of the noise. This dependence applies if the channel is an ideal filter and the noise spectrum is white. Ifthespectralpowerdensity, $S_N(f)$, ofthenoiseisknown, thenthe information capacity of the channel is:

$$y = x\log_2\left[\frac{1}{x}(1 + z_S / z_N)\int_0^x \log_2 S_N(f)df\right], \quad (2)$$

where f is the frequency.

According to the calculations, experiments on the "machine operator" system and based on the fact that the operator has to manage the technological, power and operational processes, there is a unique opportunity to optimize the quality and performance of the control process for individual machines through system integration. For this purpose, technological operations with high performance needto collect, handle and use full information about the basic processes within theis operation, e.g. those which relate to the production of agricultural products, their storage and processing. This flow of information is continuous. A majority of technological processes in agriculture are deterministic but stochastic. Most of them are stationary ergodic which enables to apply proactively the control and to monitor the quality of implementation to optimize the functioning of the management system associated with food production. Figure 1 shows the main control objects of an agricultural field crop production unit. Figure 2 presents a block diagram of a wireless sensor network (WSNS) automated for information management systems of its field units.

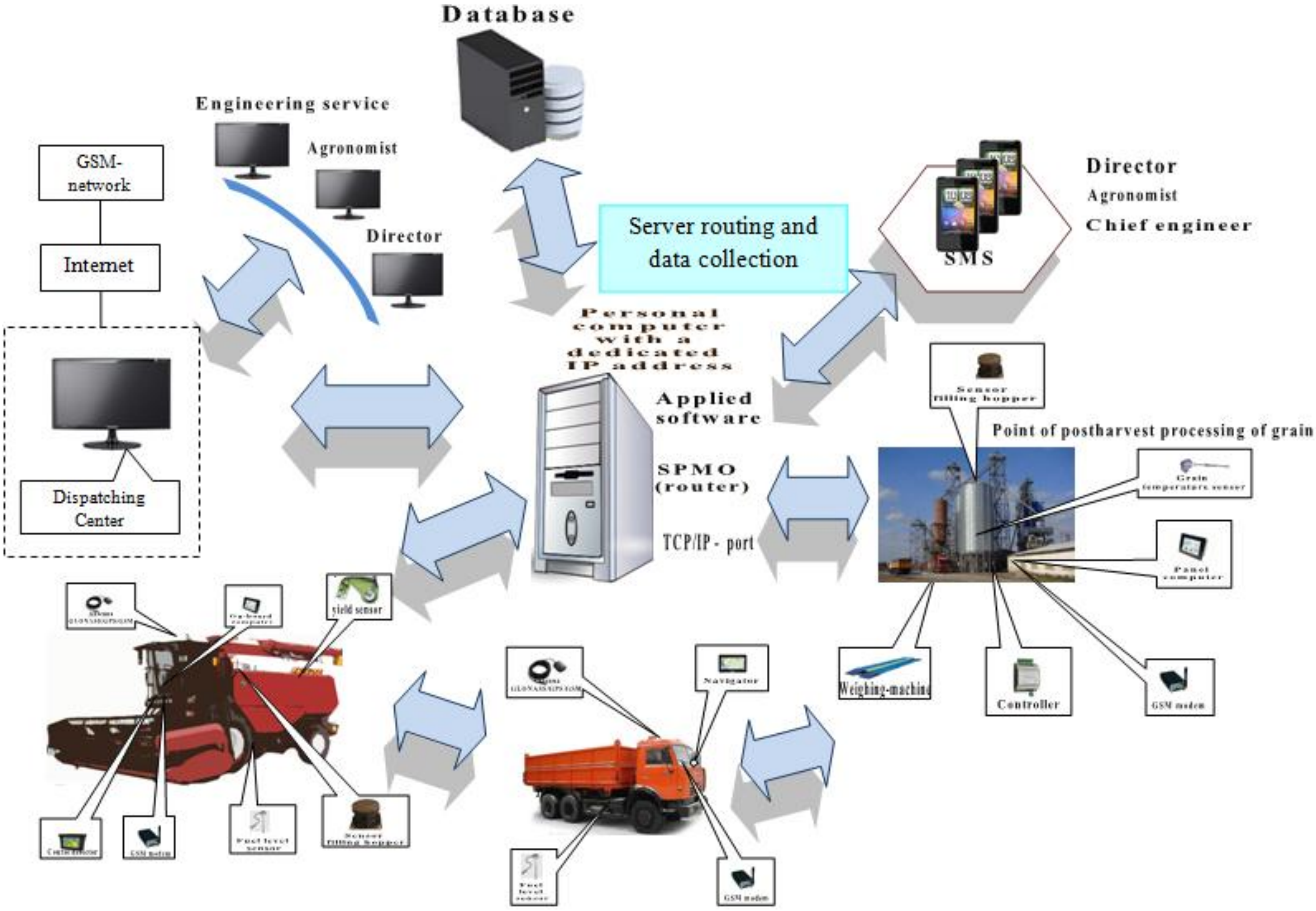

Figure 1: Information flow and automated control system for crop collection and processing

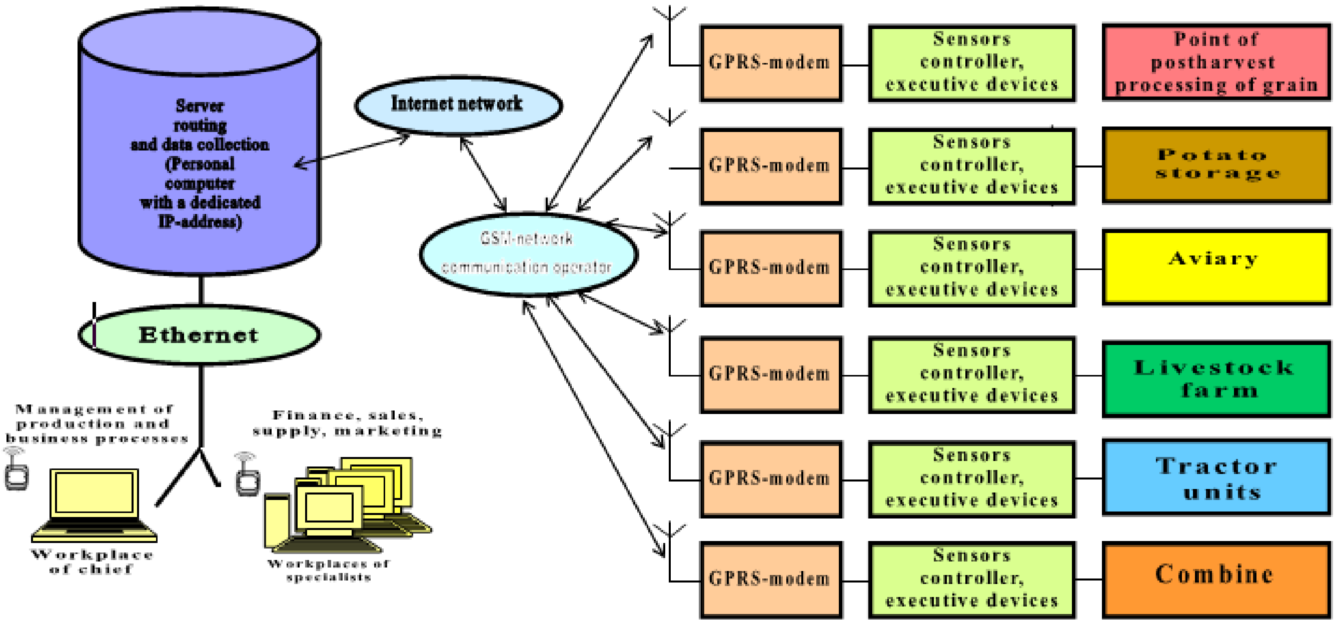

Figure 2: The block diagram of a wireless automated information management systems of fieldunits

2.2. System Hardware and Software

In order to reduce the time and direct cost of developing software applications and minimize the software development costs, it is common to use the so-called SCADA systems that provides a standard communication protocol to access and visualize information from the programmable controllers and distributed sensors. Development of SCADA system has attracted large investments and is now used widely as an industry standard. Therefore, developers of software for process automation rely heavily on SCADA system elements. Currently, the mostly widely used SCADA systems in Western Europe and Russia are In-Touch, FIX, Factory Link; most of which have been developed in the United States. Examples of some SCADA systems which were developed in Russia are: Trace Mode, Jmage and Good Help. The benefits of a SCADA system are:

- The opportunity to develop afully autonomous control system by a reasonably qualified specialist;
- Means of gathering information from a lower-level devices;
- Management and registration of the emergency signals;
- Provision of storage media and post-processing capabilities;
- Primary means of processing information;
- Visualization of information in the form of graphs and charts.

A vast majority of SCADA systems implemented in Windows which allows for a high degree of integration of these systems. Each system manages actuators, collects data from sensors, processes information, services operator workstations and database servers. It is clear that for effective functioning in this heterogeneous environment the SCADA system should ensure a high level of network server in standard media (e.g. ARCNET, ETHERNET) and using standard protocols (e.g. NET-BTOS, TCP / IP), as well as to provide support for a most popular network standard in the class of industrial interfaces (e.g. PROFIBUS, CANBUS, LON, MODBUS).These requirements are, to some extent, satisfy almost all of the modern SCADA systems, with the only difference that the set of supported network interfaces are different[5].Integrating disparate automation systems with a variety of hardware and software should be based on international standards, have a wide range of support functions and have the following structure:

(i) Low levelautomated control systems. These local automation systems are installed in tractors, agricultural appliances, transport vehicles, equipment for post-harvest grain handling, potatoes and vegetable storage, etc. This equipment is sensors, controllers, modules for the collection of discrete, analog, time and spectral information, modules for managing the actuators, communication modules, remote input-output terminals. This level is self-contained, i.e. in the absence of communication with the upper level it is able to work without any loss of information, and to exercise autonomous control in normal and emergency operation. At this level it is common to have a reconfiguration controller to change the process and get local control map through a special output device connected to a serial interfaces (e.g. RS232 or RS485).

(ii) Medium level of operation/process control. This is the level of human-machine interfaces, operator control and cross-process interaction. The equipment used here basically workstations. This equipment is of varying degrees of complexity and security depending on the size of the agricultural complex. Software used here is standard for a SCADA system and it adopts proprietary products with a broad functionality. An operational and control server also provides the collection and storage of process data, and automatic calculation of the performance of the hardware (ITA, harvesters, processing equipment in the processing and storage of agricultural products), ensure the overall progress of work, observes main targets, exercises the centralized control of production and technological processes, visualizes the production process in the convenient form for managers, prepares operational reports and transmits these reports to individual services.

(iii) High level control for the whole complex. This is an integrated level of information for the whole agricultural complex. The equipment used at this level includes a database server and client computers and their users. Data are coming from lower levels are pre-processed. The interaction of all these levels provides the organization of a common information space. For fast integration of all of these levels into a single information system it is necessary to use software and hardware that support common standards through A valid TCP / IP protocol that allows the free flow of information between various levels of control and the perception of this information by any application. Mobile communication and remote stationary objects (local system) should have special modules for transmitting and displaying information in the Web standard.

Automated complex system structure and basic hardware and software components must meet the following criteria: (i) the ability to perform automated software development, monitor and control the process in real time; (ii) it should be a bus/modular architecture system with a high degree of openness, scalable and flexible in terms of hardware and software that comply with international standards; (ii) basic hardware/software components should be in large-scale production and their upgrades should be available readily for the entire life of the system; (iii) the system must support voice and telemetry mobile communication with the controllers with a built-GLONASS / GPS receiver capabilities for tracking of moving objects (e.g. position and speed); (iv) it should have a built-in GSM-terminal to access the Internet services that provides delivery of messages and receive commands via TCT/IP-connection using packet technology (GPRS) or short messages (SMS) on the specified telephone numbers; (v) the communication platform must also support wired interfaces, standard cable connections, power supply network, radio and the Internet; (vi) the system should be reoriented without significant cost on the composition and the functions they perform different processes, quickly respond to any changes in the production cycle or environment; (vii) the system should carry out archiving of data for the main, auxiliary and service production operation, technological and production data, reflecting the current and past state of production of a particular crop and to render archival information in a graphic form; (viii) the storage time for an operation archive should be at least 1-2 days whereas the storage time for the averaged and filtered data should be at least 3-5 years; (ix) the archive should also store the data which relate to emergency situations. Information about any violations of the agricultural process should automatically appear on the computer server, be conveyed to engineering services and to the process control manager. The system should be able to address the emergency situation from the control server and computer related engineering services to stationary objects, such as lines of postharvest processing of grain, potatoes and vegetables storage and other related processes [6].

3. Details of the New Control System

All-Russian Research Institute of Agricultural Mechanization has developed new individual systems to manage agricultural processes. Figures 3 and 4 show the designs created for the management of agricultural objects which control the seeding process. The device has the following functions. It carries out an automatic control of seeding, monitors the level of seed and fertilizer hoppers, coordinates and locates the position of the mobile unit in the field which is treated, measures the speed of the mobile unit and the amount of the treated area, measures and controls the distance traveled and time of work in the field. The device performs automated driving on the path equidistant from the first pass with the error not exceeding15 cm.The device carries out the collection, storage and recording of current information in an additional memory block that is followed by the subsequent storage in a personal computer. The device also performs the adjustment of its position relative to the baseline [7].

Figure 3: A new automated system to control Kombi band seeding of grasses and grass mixtures around grasslands and pastures with the use of global navigation and positioning.

Figure 4: A photograph of the self-tuning system to control the stationary objects used for crop production

The system shown in Figure 4 is designed to monitor and to control technological processes of agricultural stationary objects, such as items of post-harvest processing of grain, potato and vegetable storage facilities and greenhouses. The system includes a PC with software controller, input/output (I/O) modules, sensors, and communication lines. The maximum length of the wired line connected to the computer module is 1200 m. By using the radio this range can be extended to 5 km. In the case of the GSM connection the range is limited only by the cellular coverage area.

4. Discussion and Conclusions

This paper presents the requirements for a system that manages automatically individual agricultural machines and objects in farms which are used to seed, crop and process agricultural produce. It is based on advanced technologies which rely on radio communication devices, microprocessors and global navigation. The system consists of standardized elements and allows, if necessary, to add electronic components and to program individual subsystems through the central computer. The result of our analytical and experimental studies was a unified information complex farm management system. This system is suitable for optimizing the management of agricultural companies, farms and mobile units (e.g. tractors, combine harvesters and trucks) as well as stationary items. This systems is based on unified microprocessor elements and it enables to increase productivity and improve the quality of agricultural products.

References

[1] J. De Baerdemaeker, Ramon H., Anthonis J., Speckmann H., Munack A. Advanced technology and automation in agriculture.Control Systems, Robotics and Automation - 19. 2009. ISBN: 978-1-84826-158-7

[2] Ivaschuk O.A., Konstantitnov I.S., Arkhipov O.P. Approaches to the development of automated control system "Smart firms". J. "Herald Eagle" GAU Volume 5. 2012. ISSN:1990-3618. eISSN: 2223-4802.

[3] Anom S.W., Shibusawa S., Sasao A., Sakai K., Sato H., Hirako S., Blackmore S. Soil parameter maps using the real-time spectropnotometer. In *Proceedings of Fifth International Conference on Precision Agriculture (CD),* July 16-19, 2000. Bloomington, MN. USA.

[4] Boegena H., K. Scbulz, H. Verrechken. Towards a network of observatories In terrestrial environmental research. Advances in Ceosciences Volume 9. 2006. ISBN: 9812709886.

[5] Charles, K., Stenz A. Automatic Spraying for Nurseries. USDA Annual Report, September 22, 2000-August 31. 2003, USDA. USA. Project Number: 3607-21620-006-03.

[6] Erl T. Service-Oriented Architecture (SOA): Concepts, Technology, and Design. Prentice Hall. Indianapolis, IN. 2005. ISBN-13: 978-0-13-185858-9.

[7] Kuznetsov I. M., Makeev M. V. The methodology for the development and implementation of information system of operational management of agricultural production in the region. VIESH. J. "Electrosvyaz", № 2, 2009. ISSN: 0013-5771.