Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 1, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SMART GARDEN INTELLIGENT CONTROL SYSTEM IN COMMERCIAL HORTICULTURE AND ITS PRACTICAL IMPLEMENTATION

Andrey Anatolyevich ZAVRAZHNOV[1], Anatoly Ivanovich ZAVRAZHNOV[1], Igor Alexandrovich ELIZAROV[2], Victor Nikolaevich NAZAROV[2], Alexander Alexandrovich TRETYAKOV[2]

[1]Michurinsk State Agrarian University, 101 Internatsional'naya Str., Michurinsk, Tambov Oblast, 393740 Russia, Email: noc-inteh@yandex.ru, zavrazhnov.a.a@mail.ru
[2]Tambov State Technical University, Tambov, Russia, Emails: elial68@yandex.ru, nazvic@yandex.ru, tsasha74@mail.ru

Corresponding author: noc-inteh@yandex.ru, zavrazhnov.a.a@mail.ru

Abstract

This article discusses the Smart Garden concept in the frames of development of modern commercial horticulture. Composition and purposes of the automated complex elements are presented, intended for adjustment of soft- and hardware of intelligent control system of commercial garden. The structure of intelligent monitoring and control system for the automated complex is presented. Selection of LoRa wireless standard and network for data acquisition from territorially distributed monitoring and control sensors is substantiated. A variant of development of automated technologist workstation for Smart Garden automated complex is discussed. It has been established that an increase in the yield of fruit and berry plantations by 20% will provide a return on capital investments of about 200 thousand rubles per hectare within one year.

Key words*: *Smart Garden, automated complex, LoRa, SCADA, automated workstation (AWS)

INTRODUCTION

Nowadays breakthroughs in the sphere of commercial horticulture are related with competences providing implementation of advanced production technologies and digital transformation, based on PC, smart, high precision and information components integrated with smart control system of production and engineering processes.
This approach creates engineering system combining advantages of serial production and, at the same time, flexibly adjusted for the currently required output, as well as characterized by high customization (personalization) aiming at quick response to market demands.
In the field of engineering support and maintenance of commercial horticulture, the main challenge is development of cardinally new services based on actively developed infrastructure of the Internet of Things, cloud computations, smart technologies, precision agriculture, continuous monitoring and diagnostics of phyto-state of plants, robotized devices.
The Digital agriculture program was developed in the frames of Digital economy program, it is a goal setting tool of social and economic development of the Russian Federation.
The provisions of the Digital agriculture are compared with the initiatives of Industry 4.0 in Germany, Advanced Manufacturing Initiative in the USA, Factories of the Future in the EU, Made in China 2025 in the PRC, and other national programs of digitalization, which are successfully implemented in science intensive and hi-tech spheres of economy.
The terms such as Agriculture 4.0 and even Agriculture 5.0 are widely used in scientific sphere.
The Digital agriculture program highlights some key trends of digital transformation of agriculture, which should be implemented in the form of expanded integrated projects, one

of each is the Smart Garden project [3, 14, 15].

The authors have determined the initial list of provisions and tasks to define, to generate, and to identify the initial concept, principles, attributes, and model architecture of the Smart Garden category, that is:

(1)Creation of unified information space providing inter-operability: capability of two or more systems of various physical essence to exchange information and to apply the information acquired during the exchange.

(2)Development of integrated engineering solutions providing continuous phyto-monitoring and monitoring of ambient environment (sensorics).

(3)Development of integrated engineering solutions providing automated analysis of monitoring data and decision making (smart control).

(4)Development of integrated engineering solutions providing rapid execution of obtained decisions even without human involvement (automation and robotization).

(5)Development of network of test sites for generation of engineering solutions in the format of Smart Garden.

MATERIALS AND METHODS

According to the definition of Digital Agriculture program, the category Smart Garden is an intelligent system of preparation, execution, and control of all procedures of cultivation of horticulture products using robotized unmanned machines and devices.

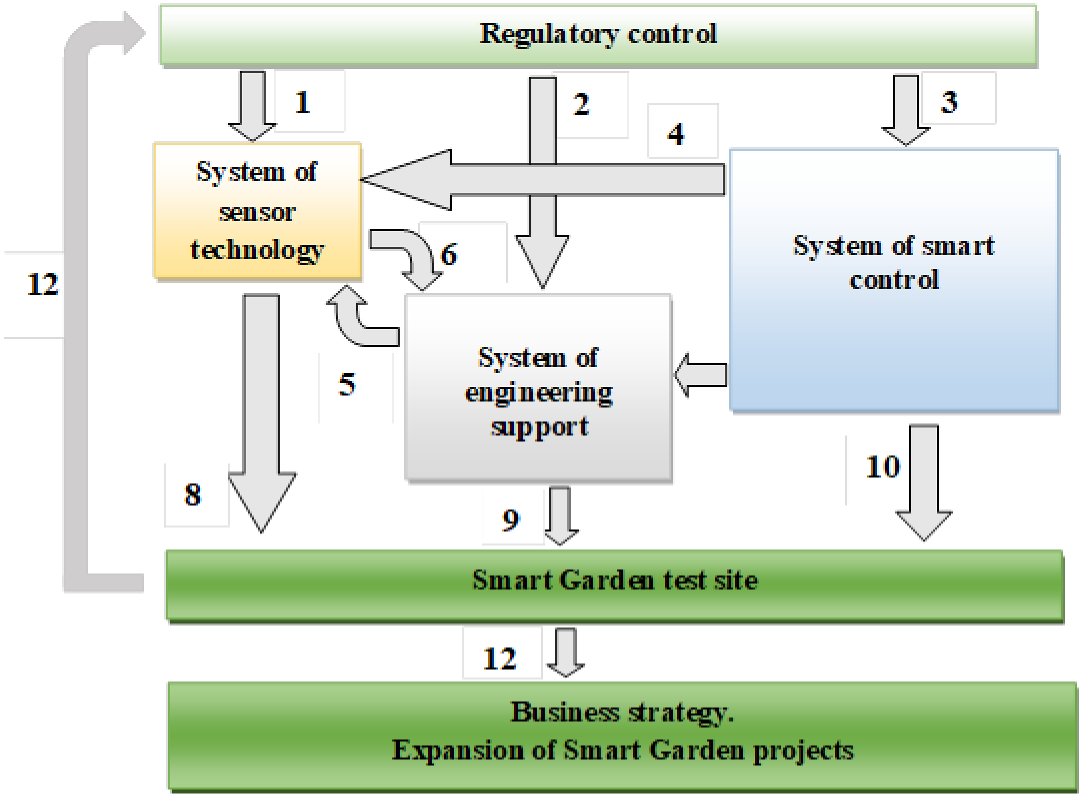


Fig. 1. Provisions and identification tasks of Smart Garden

1 – Development of model structure of sensor technology system; 2 – Development of model architecture of engineering support based on cyber physical systems, mechatronic modules and customized devices; 3 – Development of principles and smart control and decision-making system; 4 – Development of control system of sensor technologies; 5 – Engineering support and maintenance of sensor technologies; 6 – Machine monitoring using elements of precision agriculture; 7 – Development of control system of machine technologies; 8 – Verification and testing of sensor technologies; 9 – Validation and testing of prototypes and simulation samples; 10 – Verification and testing of smart control system for production and engineering processes; 11 – Validation and adjustment; 12 – Development of business strategies and provisions for expansion and commercialization of Smart Garden project

Source: Compiled by authors.

In the frames of solving the formulated problems, the scientists of Michurinsk Agrarian University and Tambov State Technical University arranged Smart Garden test site with elements of smart monitoring and control system for objects of intensive garden.

The main mission and goal setting of the Smart Garden test site are selection, testing, and practical implementation of best global and own engineering solutions with subsequent expansion and implementation in Russian horticulture farms.

This article presents the experimental results and development of automated smart drip irrigation system as exemplified by Smart Garden test site.

Figure 1 illustrates the flowchart of interaction of provisions and tasks identifying the Smart Garden category at current stage of development of commercial horticulture.

RESULTS AND DISCUSSIONS

According to Fig. 1, Smart Garden is comprised of smart monitoring and control systems which are integrated by module principle and include the following components [3, 9, 13]:

(a)Distributed subsystems of data acquisition of soil state (moisture, temperature, water potential of soil and its salinity);

(b)Climatic subsystems (air temperature and moisture, illumination level, wind speed, amount of precipitations);

(c)Stations of phyto-monitoring measuring tree parameters (for instance, tree body thickness, fruit size, and others);

(d)Basic station with backup power source (uninterrupted power source with solar cell);

(e)Actuating subsystem responsible for drip irrigation and fertilizing;

(f)Automated workstation (AWS) of technologist or agronomist with integrated system supporting decision making.

In addition, the smart monitoring and control system is characterized by additional opportunities [1, 3]:

(i)SMS notification: in the case of emergency situations due to technical or engineering reasons, the control system automatically notifies respective persons by SMS. This significantly increases efficiency of response to emergency situations.

(ii)Connection to cloud services via wired or wireless Internet.

Cloud technologies provide remote access to the monitoring and control system from anywhere with the access to Internet. User performs access to cloud service using web interface from any computer or tablet.

Modern commercial horticulture is characterized by gardens positioned in sufficiently large territories. It is reasonable to acquire data from numerous distributed sensors using wireless communication channels. Herewith, it is desirable that the sensors are equipped with independent power supply for operation in several years without replacement [7, 10, 11,12].

In two recent decades, numerous wireless standards and networks have appeared meeting the requirements of constantly increasing data amount: GSM, GPRS, 3G, LTE, Wi-Max, Wi-Fi, ZegBee, LPWAN [8].

One of the most popular LPWAN networks in the world is based on LoRa technology: LoRaWAN [6].

This technology was selected as the main communication technology in pilot project of Smart Garden test site.

LoRa technology was selected for control system due to its unique features:

(1)High signal transmission range in comparison with other wireless technologies.

(2)Very low power consumption.

(3)Good data protection.

Figure 2 illustrates flowchart of automated smart system of drip irrigation comprised of three-level hierarchy. The operator receives information about soil moisture and controls the irrigation system through the irrigation control panel, while receiving data on the amount of water used.

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 1, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

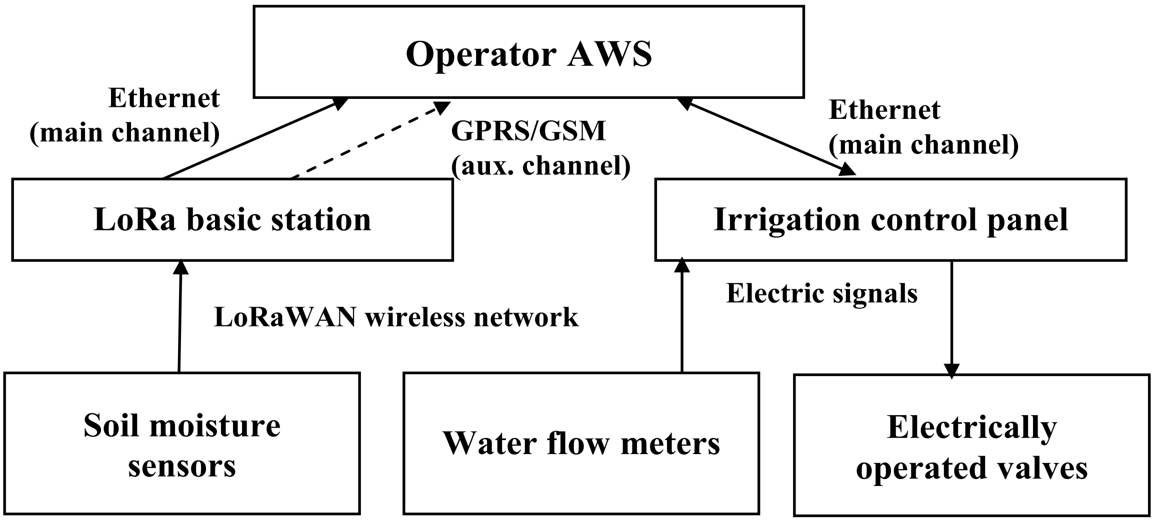


Fig. 2. Flowchart of automated smart system of drip irrigation
Source: Compiled by authors.

Figure 3 illustrates the modules of data acquisition about moisture and temperature of soil, as well as temperature in crown near tree body (3a), and climatic system (3b) measuring temperature and humidity of ambient air.

a) b)

Fig. 3. Data acquisition modules of soil and ambient air state
Source: Compiled by authors.

The equipment of Russian manufacturer, Vega-Absolut company, was selected as preferred variant supporting LoRa technology for development of Smart Garden control system.

Air temperature near soil surface and in tree crown was measured by sensor with LoRaWAN protocol: TD-11; the soil moisture was measured by sensors with 4…20 mA output signal, which were connected to LoRaWAN converter: TP-11.

In addition to transmission of signals of sensors with 4…20 mA interface to LoRaWAN network, TP-11 is also equipped with two discrete open collector outputs and can be used as control device. In addition, the device is equipped with two guard inputs. Ambient air moisture was measured by sensors with 4…20 mA output signal, TP-11 converter.

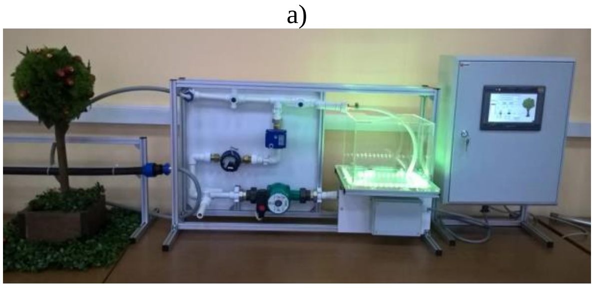
All information from the sensors is transmitted via LoRa radiochannel to the basic station (Fig. 4, a).

The basic station BS-2 is intended for deployment of LoRaWAN network at the frequencies of 863-870 MHz range. The basic station is fed via Ethernet channel; in addition, communication with the server can be executed via 3G channel.

The actuating subsystem of drip irrigation and fertilizing (Fig. 4, b) is based on Russian industrial controller PLK-100 (OVEN company). The actuating subsystem can operate in the mode of either independent or automatic control.

In the mode of independent control, the operator can preset programs of irrigation and fertilizing directly from operator control panel. In automatic mode, the controller executes the control commands generated at upper control level: at AWS of technologist.

a)



b)

Fig. 4. Basic station BS2 and uninterrupted power supply (a), actuating subsystem of drip irrigation (b)
Source: Compiled by authors.

The technologist AWS is based on Russian SCADA system: KRUG-2000, and performs the following functions [2]:
(1)Reception of basic station information from all remote distributed subsystems of data acquisition about soil state, climatic subsystems, phyto-monitoring stations, main controller of actuating system of drip irrigation;
(2)Processing, archiving, visualization of acquired data in form convenient for operator;
(3)Automatic generation of alarm signals in the case of emergency situation with opportunity to send SMS to interested persons;
(4)Logging of all operator actions;
(5)Recommendations to operator on drip irrigation, fertilizing, and other provisions.

Figure 5 exemplifies visualization of monitoring and control of drip irrigation of Smart Garden test site.

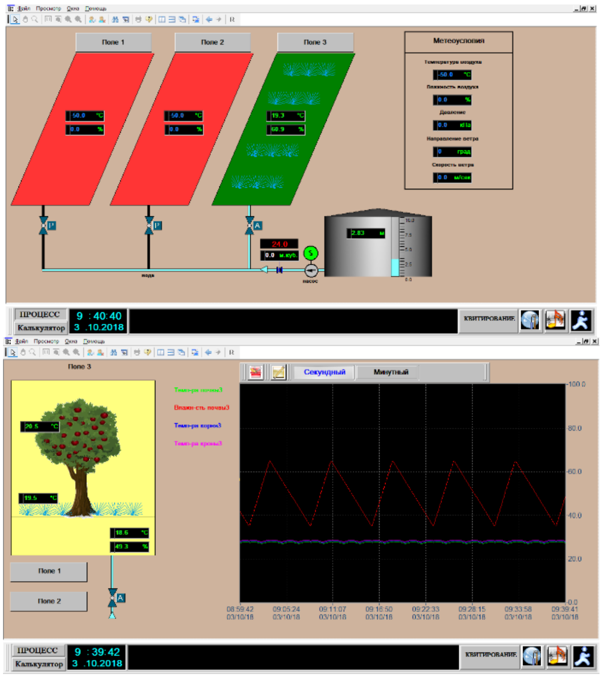


Fig. 5. Operator AWS video frames
Source: Compiled by authors.

A peculiar feature of smart monitoring and control system is the well developed algorithmic support and software. Mathematical provision is based on module principle and includes the modules for processing of measured data from sensors; the module of control commands for pumps and valves; the modules for prediction of irrigation and fertigation variables, and others. The modules of formation of control commands and the modules for prediction of irrigation and fertigation variables interact with database of smart decision-making system where data are accumulated on variables of hydroponics solutions, vegetation species and other parameters of irrigation and fertigation. This allows to develop the most optimum recommendations on drip irrigation and fertilizing.
Fertilizer metering devices are an important element of supply of hydroponics solution (fertigation) [4, 5]. Fertilizers are mixed in mixers. These devices produce hydroponics solution with predefined composition and EC and pH properties. Mixer provides respective ratios of water, concentrated solution of

fertilizers and acid. Mixer is equipped with EC and pH sensors, which allows to control and to monitor these variables in soil solution.

Fertigation is carried out automatically depending on soil moisture level, solar activity, seasons, and other variables. The smart control system allows to preset various modes of irrigation frequency, various parameters of hydroponics solution (EC, pH), which can change at different times. The information from sensors is taken into account during planning of irrigation cycles, it is also applied during simultaneous fertigation of various sites.

The use of modern information technologies, software and hardware for automation and control will significantly increase the economic efficiency of industrial gardening, the environmental safety of marketable products, and improve product quality. With the correct implementation of the Smart Garden concept of an intelligent system for managing industrial horticultural objects, the economic efficiency of the site will be several times higher than in the case of using traditional technology.

According to preliminary estimates, an increase in the yield of fruit and berry plantations by 20% will ensure a return on capital investments of about 200 thousand rubles per hectare within one year.

CONCLUSIONS

The proposed application of wireless technologies is sufficiently universal and can be applied nearly for overall range of engineering and production processes in modern commercial horticulture.

A restrictive factor in distribution of such technologies is low awareness of this type of data transfer as well as its low distribution in general and commercial horticulture in particular.

ACKNOWLEDGEMENTS

The studies were carried out at the premises of Budagovsky R&D Center, Michurinsk State Agrarian University, and were supported by the Governmental contract of the Ministry of Agriculture of the Russian Federation No. AAAA-A20-120011400206-1, entitled "Development and implementation of integrated system of distant sensing and technologies of precision agriculture as exemplified by Smart Garden test site".

REFERENCES

[1]Artyushin, A.A., Smirnov, I.G., Khort, D.O., Filippov, R.A., 2016, Osobennosti razrabotki intellektual'noy sistemy upravleniya v sadovodstve [Development of smart control system for horticulture], Vestnik Michurinskogo gosudarstvennogo agrarnogo universiteta, 2: 148–153.

[2]Elizarov, I. A., Tret'yakov, A. A., Pchelintsev, A. N., Pogonin, V. A., Nazarov, V. N., Onevskiy, P. M, 2015, Integrirovannye sistemy proektirovaniya i upravleniya: SCADA-sistemy [Integrated design and control systems: SCADA systems], Guidebook. Tambov: Mashinostroenie.

[3]Elizarov, I.A., Nazarov, V.N., Tret'yakov, A.A., Zavrazhnov, A.I., 2019, Intellektual'naya sistema upravleniya protsessami irrigatsii i fertigatsii v intensivnom sadovodstve [Intelligent control system for irrigation and fertigation in intensive horticulture], Proceedings, 1st All-Russian conference «Import substituting technologies and equipment for deep integrated processing of agricultural raw materials», Tambov, May 24-25, 2019. Tambov, pp. 498–501.

[4]Fomenko, T. G., Popova, V. P., 2010, Plodonoshenie yabloni pri kapel'nom oroshenii i fertigatsii v usloviyakh letnego perioda [Apple tree fruiting upon drip irrigation and fertigation in summer season], Plodovodstvo i vinogradarstvo Yuga Rossii, 6: 86–93.

[5]Fomenko, T. G., Popova, V. P., Belousova, K. V. 2019. Effektivnost' primeneniya novykh otechestvennykh udobrenii pri fertigatsii v plodonosyashchikh nasazhdeniyakh yabloni [Efficiency of new Russian fertilizers in apple tree fruiting plantations], Sadovodstvo i vinogradarstvo, 2: 10-17.

[6]iTechinfo. Overview of LoRa. https://itechinfo.ru/node/46, Accessed on 31.10.2019.

[7]Izmailov, A. Yu., Smirnov, I. G., Khort, D. O., 2018, Tsifrovye agrotekhnologii v sisteme «Umnyi sad» [Digital agricultural technologies in Smart Garden system], Sadovodstvo i vinogradarstvo, 6: 33–39.

[8]Kiya, O. 2013, Tekhnologii i standarty, primenyaemye v sovremennykh promyshlennykh besprovodnykh setyakh [Technologies and standards applied in modern industrial wireless networks], Control Engineering, Russia, 5(47):70–72.

[9]Krasnyanskii, M.N., Yelizarov, I.A., Tret'yakov, A.A., Muromtsev, D.Yu., Zavrazhnov, A.A., 2018, Primenenie tekhnologii LORA v intensivnom sadovodstve [LoRa technology in intensive horticulture], Proceedings of the 1st International

Conference «Digitalization of agroindustrial complex». Vol 2. Tambov, October 10-12, pp. 16–18.
[10]Okayama, Ts., Miyawaki, K., 2013, The «Smart Garden» System using Augmented Reality, IFAC Proceedings Volumes, 46(4): 307–310.
[11]Safiullin, R.N., Afanas'ev, A.S., Reznichenko, V.V., 2019, Kontseptsiya razvitiya sistem monitoringa i upravleniya intellektual'nykh tekhnicheskikh kompleksov [Concept of development of monitoring and control systems for smart complexes], Zapiski Gornogo instituta, 237: 322–330.
[12]Voinova, N.F., 2014, Sovremennoe sostoyanie teorii, sredstv i metodov avtomatizatsii tekhnologicheskikh protsessov sel'skokhozyaistvennogo proizvodstva [State-of-art status of theory, means and methods of agricultural production processes], Vestnik VIESKh, 2(15): 64–67.
[13]Zavrazhnov, A., Zavrazhnov, A., Lantsev, V., 2015, Information modeling technology in industrial horticulture, Russian Journal of Horticulture, 2(1):5–12.
[14]Zavrazhnov, A.A., Zavrazhnov, A.I., Lantsev, V.Yu., Muromtsev, D.Yu., Elizarov, I.A., 2018, Kontseptsiya «umnogo» sel'skogo khozyaistva na primere otrasli promyshlennogo sadovodstva [Concept of smart agricultural farm as exemplified by commercial horticulture], Proceedings, 1st International Conference «Digitalization of agroindustrial complex». Vol 2. Tambov, October 10-12, 2018, Tambov: TGTU Publishing House, pp. 12-17.
[15]Zavrazhnov, A.A., Trunov, Yu.V., Kulikov, I.M., Zavrazhnov, A.I., 2019, Kontseptsiya nauchnykh issledovanii «Sadovodstva budushchego» [Future Horticulture: concept of scientific study], Plodorodie, 1(106): 51-55.