REMOTE SMART BIOSENSORS FOR PRECISION FARMING AND ENVIRONMENT PROTECTION

Volodymyr Romanov, Dmytro Artemenko, Igor Galelyuka, Oleksandr Palagin, Yevgeniya Sarakhan

***Abstract**: In the article features of new portable biosensor devices of "Floratest" family for express-diagnostics of plant state in real time mode are described. The devices are developed and created in V.M.Glushkov Institute of Cybernetics of NAS of Ukraine. Today these devices are used in precision farming and environment monitoring, but new application of these devices is more challenging. Standard biosensor device can be used as part of data acquisition systems or independently, but all measurements are made in manual mode (several measurements per hour). The new one is wireless biosensor. The biosensors are integrated into sensor networks and used in precision farming and environment protection. Proposed wireless biosensors have significant differences from free-running devices. Wireless biosensors with radio transceivers are placed on test plants and data reading from set of plants is executed at the same definitive time by remote mobile computer or other mobile tools, for example, electric unmanned quadcopter. Due to it is possible to get hundreds of measurements from different parts of planted area or woodland. Implementation of proposed biosensor devices with radio channel and sensor networks on their base to agriculture and environment protection makes it possible to increase efficiency and quality of agricultural products, and spare fertilizers, water and energy resources, timely protect plants from infections and anthropogenic impact.*

***Keywords**: wireless biosensor, precision farming, environment protection.*

***ACM Classification Keywords**: J.3 Life and Medical Sciences - Biology and Genetics*

Introduction

Unforeseen changes of climate, anthropogenic impact and fast spreading of viral and bacterial diseases of agricultural and forest plants demonstrated acute necessity to develop and full-scale produce smart biosensor devices for express-diagnostics of plant state and measuring results of impact of climate, anthropogenic, viral and bacterial loads on the plants.

Therefore, acquisition of live and objective data about plant cover state in most cases is very important factor, which causes future strategy of keeping megalopolis trees, forests and agricultural lands and proper decision making. Certainly, it would be ideal to obtain information about improvement or worsening of plant state beforehand, but not after event. It lets to avoid increasing costs, save harvest from possible loss and protect forests and megalopolis trees from viral, bacterial and anthropogenic loads.

Development of information and biosensor technologies over last 20 years caused creating and implementation of sensor networks, which are the distributed data acquisition and processing systems with remote gathering of measured data, in many areas of human activity. Such systems include smart sensors, communication lines, transmitters and receivers, central control stations, which gather and accumulate information.

Today it is impossible to imagine the precision farming or environment protection technology without such important element as decision-making and operation generating system. Data from system of primary sensors, placed directly on agricultural fields or woodland trees, can be used as basis for decision making. Quality and completeness of data acquisition determine the correctness of decision making about implementation of necessary operations for harvest increasing, plant protection and costs reducing.

It is necessary to note, that functional possibilities of decision-making system in precision farming and environment protection significantly are determined by quantity, quality and frequency of data acquisition and data processing.

Acquisition of live and objective data of plant or tree state in most cases is very important factor, which causes future strategy of keeping agricultural lands and woodlands and proper decision making. Certainly, it would be ideal to obtain information about improvement or worsening of plant or tree state beforehand, but not after the event. It lets to avoid increasing costs and save harvest and trees from possible loss.

The mobile and traditional data acquisition technologies play an important role in precision farming and environment protection as primary data sources. For this aim in V.M.Glushkov Institute of Cybernetics of NAS of Ukraine it is developed wireless data acquisition system, which in real-time obtains information about plant state on large territory of agricultural fields and woodlands. Structure organization of developed data acquisition systems are presented in [Palagin, 2011].

Portable Biosensor Device

As tools for data acquisition it is possible to use original portable devices of "Floratest" family (see fig.1), which were developed and prepared for full-scale production in V.M.Glushkov Institute of Cybernetics of NAS of Ukraine [Romanov, 2012]. Portable biosensor "Floratest" is used for plant state monitoring in real time mode. The device is based on method of chlorophyll fluorescent induction [Kautsky, 1931], and provides the estimation of photosynthesis process quality, which is the main process of plant development. "Floratest" devices are used now as part of data acquisition systems or independently for design of methods of following task solutions:

- express estimating plant life activity after drought, freeze, imps, pesticide application etc.;
- express estimating optimal dozes of fertilizers and biological active admixtures. It makes possible to decrease cost of final products, reduce harmful substance and nitrate content in fruits, vegetables and soil;
- express estimating pollutions of soil, water and air by pesticides, heavy metals and industrial emissions;
- forecasting future crop in precision and insurance farming;
- ecological monitoring of state of megalopolis planting and forest trees;
- profound scientific research in plant physiology area in universities and schools.

Similar devices are manufactured by foreign companies, but their unit price is about several thousands of US dollars, what is 3-5 times higher than price of "Floratest" device (estimating price is 500 USD). In addition applied software and amount of methods of foreign devices are limited and they are designed as closed systems. Thereby if someone needs method and program, which are absent in device manual, it is impossible to add new methods and programs developed by customer to the device. Furthermore it is impossible to make update of hardware and software of foreign devices by user for spreading of application scope. As opposed to foreign devices the "Floratest" device is designed as open system and it makes possible to upgrade device hardware without device redesigning.

In V.M.Glushkov Institute of Cybernetics there were designed industrial methods for application of "Floratest" device. Field testing of the device was performed in Ukraine and Germany. On this base two license agreements were signed for serial production of "Floratest" device in conditions of modern contract manufacture.

Figure 1. Portable biosensor device of "Floratest" family

Wireless Biosensor Device

Field testing devices of "Floratest" family, including in agrarian farming of Germany, showed some restrictions of its application. The data reading from one plant is lasted some minutes. But monocultures and woodlands are growing in large areas and due to get data from these areas for crop monitoring it is necessary to make thousands of measurements. For this purposes there are needed dozens of the devices and large service staff of high-level skill.

To develop technology of express estimation of plant state based on chlorophyll fluorescence induction method for precision farming and environment protection it was designed and prepared for serial production remote smart wireless biosensors with embedded radio transceiver. The functional scheme of tiny biosensor is shown on fig. 2 and biosensor itself is shown on fig. 3. Before tiny sensor designing it was imposed several requirements to such sensor: long-term autonomous work, reliability of data sending and receiving, a large communication range, small size and weight, stability to climate influence. During designing tiny biosensors all requirements were complied.

High-productive 8-bit microcontroller ATmega8L (Atmel) with low power consumption drives all units of tiny biosensor. For measuring plant state it is used upgraded optical sensor of portable device "Floratest". To organize wireless channel we used small-size transceiver unit TRC105 (RFM). This unit works in the frequency range from 300 to 510 MHz, which includes the frequency for industrial, scientific and medical purposes (433 MHz). As USB-interface we used chip FT232RL. Quarts oscillator with frequency of 12,8 MHz was chosen as reference frequency source. Low-power high-precision chip AD1582ART (Analog Devices) is used as reference voltage source.

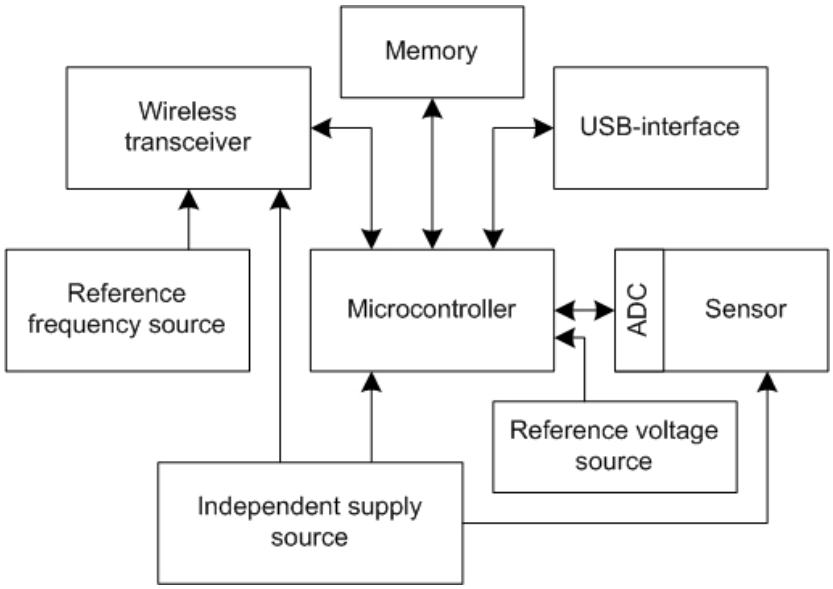

Figure 2. Functional scheme of tiny biosensor device of "Floratest" family

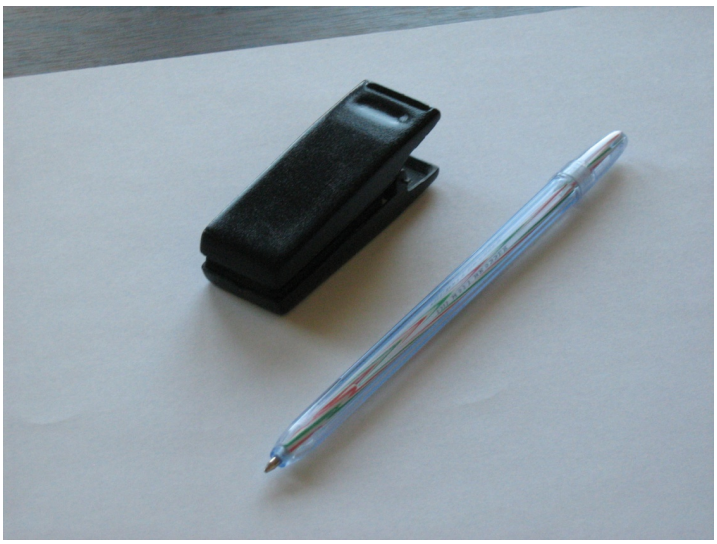

Figure 3. Tiny biosensor device of "Floratest" family

So, we designed sensor network, which includes remote smart wireless biosensors with embedded radio transceiver. Fundamental difference of proposed smart biosensors from independent devices is following. Wireless smart biosensors with radio transceivers are placed before in test plants and data reading is realized at the same definitive time by remote mobile computer. So instead of rather expensive independent device with cost price 500 USD it will be used cheap smart biosensors with cost price not more 100 USD. Due to it is possible to get hundreds of measurements from different parts of planted area or forest territory. It is very important for dynamic environment. As additional advantage it is not needed high-skill staff for smart biosensor placing.

Preliminary experimental investigation, performed in V.M.Glushkov Institute of Cybernetics, proved the advantages of changing independent devices with smart wireless biosensors, which are integrated in remote sensor network. The advantages are very important for plant state monitoring in large agriculture or woodlands.

This time it was designed and created new pilot samples of remote smart biosensor with radio-channel for express-diagnostic of plant state in precision agriculture and environment protection and developed architecture

of distributed sensor network for data acquisition on the base of developed biosensors and element interaction methods. Data acquisition will be made by means of remote servers with wireless unit or mobile unmanned tool (electric small quadcopter).

It is important to note, that proposed biosensor network with reading data by unmanned quadcopter has no analog both Ukraine and world.

Ultimate goal is design and preparing non-expensive wireless remote smart biosensors for serial production, and developing applied software for integrating remote biosensors to sensor networks. Such solution will increase the efficiency of information technology in precisian farming and environment protection as for diagnostics of viral and bacterial loads, so for monitoring impact of climate and anthropogenic factors on plants.

Implementation of remote smart biosensors with radio transceivers to agriculture and environment protection makes it possible to timely protect plants from viral and bacterial diseases and anthropogenic impact, spare fertilizers, water and energy resources.

Successful testing of independent serial devices with wired sensor, which are competitor devices of proposed to design remote smart biosensor, and dozens of orders of network sensor systems confirm appropriateness of implementation of proposed remote smart biosensors to industrial agriculture and environment protection not only in Ukraine, but in other countries of world.

Devices testing and working out methodical support took place on the experimental fields of leading organizations of Ukraine and Germany: National University of Life and Environmental Sciences of Ukraine, Institute of Horticulture of National academy of agrarian sciences of Ukraine, National scientific centre "Institute of viticulture and wine-making named after V.Ye. Tairov" of National academy of agrarian sciences of Ukraine, Institute of bioenergy crops and sugar beet of National academy of agrarian sciences of Ukraine, company "Agrostim" (Germany), the private institute of applied biotechnology "daRostim" (Germany).

Potential customers of new biosensors and data acquisition systems on their base are organizations of agrarian sector, farmers, manufacturers and distributors of fertilizers, pesticides and biological active admixtures, research institutes of National academy of agrarian sciences of Ukraine, Centers of environmental protection and Universities.

Conclusion

In the V.M.Glushkov Institute of Cybernetics of NAS of Ukraine it was designed and developed new technology of plant protection diagnostics, based on sensor network for data measurement and helicopter for data acquisition. Implementation of proposed smart biosensors with radio channel and distributed data acquisition systems on their base to agriculture and environment protection makes it possible to increase efficiency and quality of end product, and spare fertilizers, water and energy resources, timely protect plants from infections and anthropogenic impact.

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