# DATA ACQISITION SYSTEMS FOR PRECISION FARMING

**Oleksandr Palagin, Volodymyr Romanov, Igor Galelyuka, Vitalii Velychko, Volodymyr Hrusha, Oksana Galelyuka**

***Abstract**: In the article it is described two structures of data acquisition systems, which are based on the family of portable devices "Floratest" and suitable for using in precision farming.*

***Keywords**: Cautsky effect; chlorophyll; chlorophyll fluorescence induction; data acquisition system; fluorometer; portable device; precision farming.*

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

## Introduction

Unforeseen changes of climate and difficulty of using statistical data demonstrated acute necessity to develop models for forecasting crop yield and climate influence on it. These models have to be based on live data, but not only statistical ones. Acquisition of input data for these models is urgent and important task. Earth remote monitoring data (e.g. space observations) and data from surface tools for plant state monitoring can be considered as such input data. It is important to note, that these data are very significant for precision farming technology, which also operates with models for forecasting crop yield and is used for minimization of costs (e.g. water, fertilizers etc.) and maximization of harvest.

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

In the article there are is described tool for express-diagnostics of plant state, notably portable device "Floratest" [Romanov, 2007], and data acquisition systems, built on basis of these portable devices.

## TOOL FOR MONITORING OF PLANT STATE

Photosynthetic processes are the processes which supply energy to the cells of plants. Chlorophyll is the main pigment of the cells of plants. One of the main features of the molecular of chlorophyll is ability of fluorescence. The intensity of chlorophyll fluorescence depends on photosynthetic activity. After irradiation of leaf the intensity of chlorophyll fluorescent signal is increasing at first and then slowly reduces. This effect is called as effect of Kautsky [Kautsky, 1931] or effect of chlorophyll fluorescent induction (CFI). The form of this curve is very sensitive to adverse environment.

It gave possibility to develop in the V.M. Glushkov Institute of Cybernetics of NAS of Ukraine the portable device "Floratest", which estimates in several seconds the plant state after drought, frosts, pollution, herbicides etc.

without plant damage. Like human cardiogram device builds CFI curve estimated photosynthesis process, which is the base of plant vital activity.

Device and relevant diagnostic methods refer to the area of biological object researches by detecting their biophysical properties, particularly native chlorophyll fluorescent induction. Device is defined as smart biosensor with fragment plant as sensing element.

Express-diagnostic of plant state is carried out by functional features and is based on using of features of separate specific sections of CFI curve, which refer to separate areas of photosynthesis chains as diagnostic features. By CFI curve form it is easily to detect influence of one or another stress factor on the plant state.

Application areas of portable device "Floratest":

– express-estimating plant vital activity after drought, frosts, sorts coupling, pesticide introduction;

– express-detection of optimal doses of chemical fertilizers and biological additives, what lets to optimize amount of fertilizers and additives and reduce nitrates content in vegetables and fruits;

– express-detection of level of pollution of water, soil and air by pesticides, heavy metals and superpoison;

– economy of energetic and water resources during man-made watering;

– developing precision farming technology for increasing the quality of agricultural products;

– using the device in the insurance agriculture to get predicted results of future yield;

– automation of researches in the plant physiology field.

During field experiments conducting on large areas the sequence of measurements in the time causes distortion of overall results of measuring. Irregularity of ground area causes internally irregularity of plant growth parameters and future crop. Complex and multistage agrotechnical process doesn't always correlate with changes of plant passing through phenological stages, what has place in conditions of unforeseen climate changes. For estimating state of plant photosynthetic apparatus it is used classical acetone method in different modifications. This method is characterized by limited plant samples and long-term tests. So, simultaneity of measuring on the field under the same conditions lets to implement necessary technological procedures, involve necessary agrotechnology, forecast and influence on future crop in time.

It is clear, that it is impossible to provide plant state low cost monitoring of large agricultural field in short time by some wired devices. To solve the problem we need to equip data acquisition system by family of portable devices "Floratest" with communication tools.

## DISTRIBUTED DATA ACQUISITION SYSTEMS

Development of electronics and telecommunication technologies over last 10 years causes creating and implementation of electronic data acquisition systems with remote gathering of measured data in many areas of human activity. Such systems include smart sensor modules, communication lines, transmitters and receivers, central control stations, which gather and accumulate information.

As sensors in such system we use developed by us family of portable wireless devices "Floratest". Example of structure organization of developed data acquisition system is shown on Fig. 1.

In most cases the efficiency of data acquisition system work is defined by level of used technologies of data acquisition and data transmission medium. With increasing system scale the contribution of these components in

total efficiency of data acquisition system increases too. So, first of all, it is important to choose technology of data transmission. Analysis of data transmission technologies showed that it is most optimal to create such data acquisition system on basis of wireless network with mobile terminals, which use existing mobile communication systems (e.g. GSM/GPRS). In this case it is no necessity to issue the license on radiofrequency channel using and buy expensive transmission and receiving equipments. In addition, GSM network covers all territory of Ukraine and other countries.

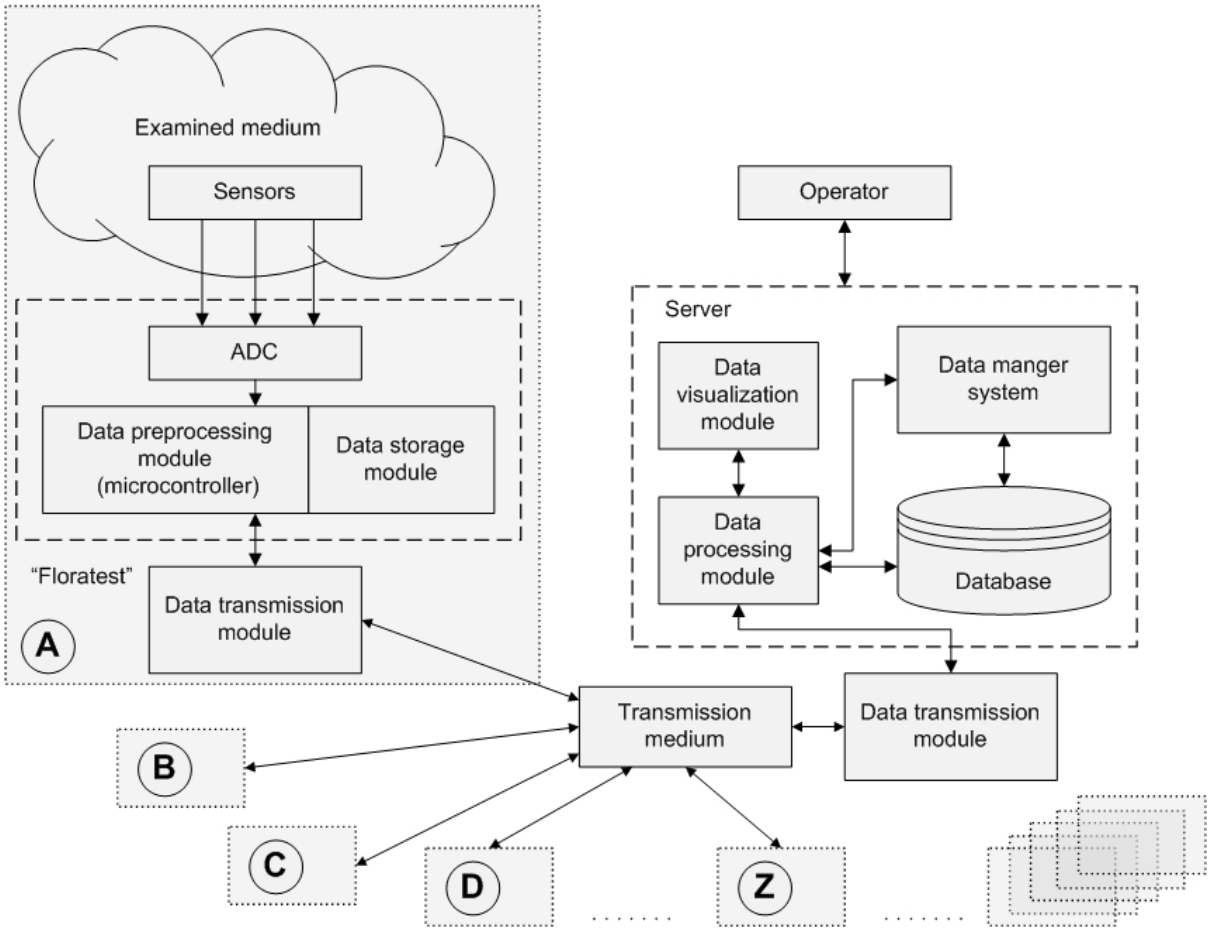


Fig. 1. Data acquisition system on the basis of device "Floratest" family

In developed data acquisition system smart portable devices are used as mobile tools for data acquisition in any country region. Measured data from portable devices are transmitted to central control station, where these data are processed, analyzed and generalized. Collected results are displayed in graphic, tabular or another form and then used for building generalized map of some region state. Map of state defines, for example, plant cover state of agricultural lands, ecological state, existence of plant diseases etc. on some territory or whole country.

In our opinion the main disadvantage of such system is next one: if you want to change or implement new applied calculation methods you need to reprogram all mobile portable devices "Floratest".

To remove this disadvantage we are developing new data acquisition system, which has significant differences from previous one. Principle of such system operation is next. Portable devices "Floratest" measure plant state

without any data processing. Then user defines the examined medium (e.g. plant sort) and "raw data" is transmitted to server. Taking into account the type of examined medium the server will process these "raw data" by means of specific calculation method. Having necessity to alter or develop new applied calculation methods we simple will put new applied calculation method on the server or replace existing one.

Taking into account technology of sensor networks the developing of new data acquisition system is very similar to developing of network element, so next tasks have to be solved:

– minimization of device dimensions;

– minimization of power consumption for long lifetime of batteries;

– polling of sensors and data transmission in digital format.

Unlike classical elements of sensor network our sensors don't support data retransmission from one sensor to another, but this feature will be examined in future.

Data acquisition system, as set of small smart sensors, which are places on the biological objects, needs, as rule, complex software on the server. Such software has to poll sensors and obtain data, control element network and set their operation modes, interpret, store and represent data from sensors.

Generally typical architecture of such system can be presented by next components: sensor module, communication unit with sensor modules, server and work terminal. Sensor module measures parameters of biological object state, in case of need partially processes measuring data, communicates with server and processes commands for work mode change. Communication unit with sensor modules provides two-side digital communication with sensor modules, saves all obtained data, transfers these data to server, retransmits control commands to sensor modules, on demand gives data from sensor modules. Server accumulates data from one or several communication units, saves all obtained data, sends saved data on demand of work terminal. Work terminal gives graphic interface to system users, provides representation, partial (in some cases full) processing and storing data for more detail processing, gives possibility to control system.

Presented architecture is classical for tasks of such type. Among system features one can note storing all data by sensor modules. It is made for increasing reliability of system in the case of server failure. In this case the data will be accumulated in the communication unit and then transmitted to the server. Communication unit with sensor modules performs minimum of intelligent functions and saves all data in "raw format". Data interpretation is made by next system components.

Typical architecture of such data acquisition system with applied calculation methods on server is shown on fig. 2.

New data acquisition system gives us significant advantages:

1) it is no necessity to alter or reprogram sensors (portable devices "Floratest") in the case of changing applied calculation methods;

2) there are no embedded applied methods, so it simplifies hardware and software of portable device "Floratest" and reduces the price;

3) automatic operation of portable device without specialist presence is possible;

4) it is large flexibility of the modernization of existing and developing new applied calculation methods.

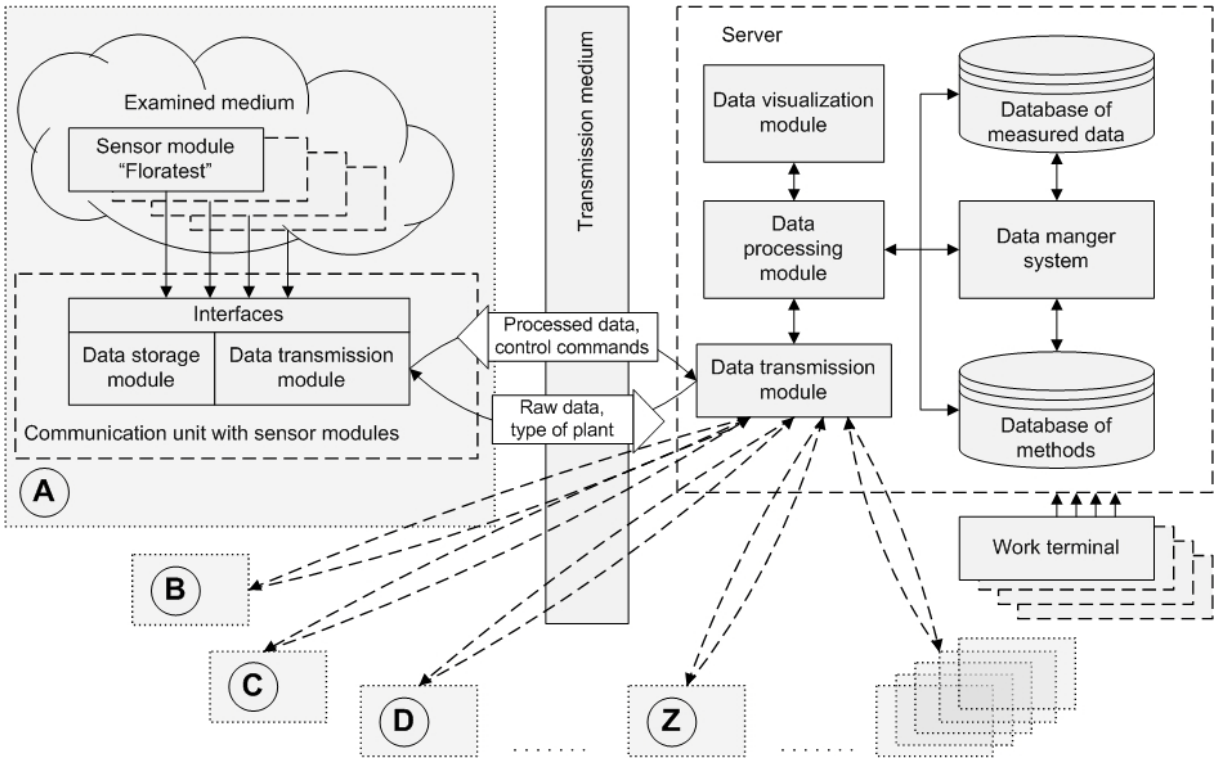


Fig. 2. Architecture of data acquisition system with applied calculation methods on server

## DATA PROCESSING ON THE SERVER

For processing of measured data on the server and searching dependences and characteristic features of curve family we used the technology of growing pyramidal network (GPN) [Gladun, 2008]. GPN belongs to class of logic - linguistic information models, i.e. such models where the main elements are not numbers and calculations. The main elements in such models are names and logical connections. Logic - linguistic models can operate simultaneously with different-type data and be described adequately by means of natural language expressions.

The model of classes of the objects, used for the decision of tasks of classification, diagnostics and forecasting, should include all the most important attributes describing a class. The model also should display for this class the characteristic logical connections between essential attributes. Generalized logical multivariate models of objects classes are the *concepts* that in logic are usually defined as ideas that reflect essence of objects. [Voyshvillo, 1967]. The concept in GPN is a generalized logical attributive model of objects' class, and represents the belonging of objects to the target class in accordance with some specific combinations of attributes.

A GPN is an acyclic oriented graph having no vertexes with a single incoming arc. Vertices having no incoming arcs are referred to as *receptors*. Other vertices are named *conceptors*. Receptors correspond to values of attributes. When the network is building, the input information is represented by sets of attributes values describing some objects (materials, relations, actions, situations, names of properties, states of the equipment, illness etc.). In the task of searching characteristic features of curve ensemble the receptors correspond to intervals of values of measured data with time stamps. Conceptors correspond to descriptions of objects in general and to crossings of objects descriptions. Conceptors represent GPN vertices. In this task conceptors correspond to CFI curves and crossings of CFI curves descriptions.

The result of network building is the formed logical expression contains logical relations, represented by allocation of *check vertices* [Gladun, 2008]. Logical expression describes the concepts in the network, defining different classes of objects. The system forms logical models of objects classes which allow taking into account influence on diagnosed or forecasting parameter of separate attributes and their various combinations as well. Besides, it is taken into account influence of "exclusive" attributes which are incompatible with diagnosed or forecasting value.

The analytical tasks, such as diagnostics or forecasting, can be reduced to the task of classification, i.e. to belongings the research object to a class of objects, with a set of properties significant for prognosis. Classification of new objects is performed by comparing the attribute descriptions of new objects with the concept, defining a class of forecasting or diagnosed objects. Objects can be classified by evaluating the value of the logical expressions that represent corresponding concepts. The variables, corresponding to the attribute values of the recognized object, set 1, other variable set 0. If the evaluated expression takes the value 1 it means that the object is included into the volume of concept.

By classification manner GPN is closest to the known methods of data mining as decision trees and propositional rule learning. The main characteristic of the pyramidal networks is the possibility to change their structure according to structure of the incoming information. Unlike the neural networks, the adaptation effect is reached without introduction of a priori network excess. Pyramidal networks are convenient for performing different operations of associative search. Hierarchical structure of the networks, which allows them to reflect the structure of composed objects and gender-species connections naturally, is an important property of pyramidal networks.

Pyramidal networks considerably decrease volumes of search operations that makes it possible to avoid the effect of "information explosion" when solving analytical problems on the basis of large-scale data. Certainly, the full advantages of pyramidal networks are appeared at their physical realization supposing parallel distribution of signals on a network. The important property of a network as means of storage of the information is that the opportunity of parallel distribution of signals is combined with an opportunity of parallel reception of signals on receptors.

## Conclusion

– It is described two structures of data acquisition systems, which are based on the family of portable devices "Floratest" and suitable for using in precision farming.

– It is shown, that data acquisition systems with common applied methods on the server let to simplify smart sensor devices but shifting data processing to server and using universal taught method of logic – linguistic data processing.

– Developing and implementation of such systems let to considerably expand area of application of portable device "Floratest" family.

## Acknowledgement

The paper is published with financial support by the project ITHEA XXI of the Institute of Information Theories and Applications FOI ITHEA (www.ithea.org) and the Association of Developers and Users of Intelligent Systems ADUIS Ukraine ( www.aduis.com.ua)

## Bibliography

[Romanov, 2007] Romanov V., Fedak V., Galelyuka I., Sarakhan Ye., Skrypnyk O. Portable Fluorometer for Express-Diagnostics of Photosynthesis: Principles of Operation and Results of Experimental Researches // Proceeding of the 4-th IEEE Workshop on "Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications", IDAACS'2007. – Dortmund, Germany. – 2007, September 6–8. – P. 570–573.

[Kautsky, 1931] Kautsky H., Hirsch A. Neue Versuche zur Kohlenstoffassimilation // Natur wissenenschaften. – 1931. – 19. – S. 964.

[Gladun, 2008] Gladun V., Velichko V., Ivaskiv Y. Selfstructurized Systems // International Journal Information Theories and Applications, FOI ITHEA, Sofia, Vol.15, N.1, 2008. – P. 5-13.

[Voyshvillo, 1967] Voyshvillo E. The Concept. MGU-Moscow, 1967, 285 p. (in Russian)

## Authors' Information

**Oleksandr Palagin** – Depute-director of V.M. Glushkov's Institute of Cybernetics of National Academy of Sciences of Ukraine, Academician of National Academy of Sciences of Ukraine, Doctor of technical sciences, professor; Prospect Akademika Glushkova 40, Kiev–187, 03680, Ukraine; e-mail: palagin_a@ukr.net

**Volodymyr Romanov** – Head of department of V.M. Glushkov's Institute of Cybernetics of National Academy of Sciences of Ukraine, Doctor of technical sciences, professor; Prospect Akademika Glushkova 40, Kiev–187, 03680, Ukraine; e-mail: VRomanov@i.ua; website: http://www.dasd.com.ua

**Igor Galelyuka** – Senior research fellow of V.M. Glushkov's Institute of Cybernetics of National Academy of Sciences of Ukraine; Candidate of technical science; Prospect Akademika Glushkova 40, Kiev–187, 03680, Ukraine; e-mail: galib@gala.net; website: http://www.dasd.com.ua

**Vitalii Velychko** – Senior research fellow of V.M. Glushkov's Institute of Cybernetics of National Academy of Sciences of Ukraine; Candidate of technical science; Prospect Akademika Glushkova 40, Kiev–187, 03680, Ukraine; e-mail: velychko@aduis.com.ua website: http://www.aduis.com.ua

**Volodymyr Hrusha** – research fellow of V.M. Glushkov's Institute of Cybernetics of National Academy of Sciences of Ukraine; Prospect Akademika Glushkova 40, Kiev–187, 03680, Ukraine; e-mail: vhrusha@gmail.com; website: http://www.dasd.com.ua

**Oksana Galelyuka** – Research fellow of Institute of encyclopedic researches of National Academy of Sciences of Ukraine; Tereschenkivska str., 3, Kiev, 01004, Ukraine