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DISTRIBUTED VIRTUAL LABORATORIES FOR SMART SENSOR SYSTEM DESIGN

Oleksandr Palagin, Volodymyr Romanov, Vitalii Velychko, Igor Galelyuka, Volodymyr Fedak, Volodymyr Grusha, Dmytro Artemenko, Oksana Galelyuka

Abstract: In the article it is considered preconditions and main principles of creation of virtual laboratories for computer-aided design, as tools for interdisciplinary researches. An important feature of this project is using the advanced multi-dimensional access method for organizing the information base of the Virtual laboratory. Virtual laboratory, what are offered, is worth to be used on the stage of the requirements specification or EFT-stage, because it gives the possibility of fast estimating of the project realization, certain characteristics and, as a result, expected benefit of its applications. Using of these technologies already increase automation level of design stages of new devices for different purposes. Proposed computer technology gives possibility to specialists from such scientific fields, as chemistry, biology, biochemistry, physics etc, to check possibility of device creating on the basis of developed sensors. It lets to reduce terms and costs of designing of computer devices and systems on the early stages of designing, for example on the stage of requirements specification or EFT-stage.

An instance of using the VLCAD is designing the Portable Device "Floratest" as Tool for Estimating of Megalopolis Ecology State. Portable device "Floratest" is aimed for express-diagnostic of plant state. It is developed in the V.M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine. Party of this device is manufactured and transferred to organizations, worked in the agricultural sector, environmental protection area, mineral fertilizer production etc. for working out of methodical tools. Using of the device for estimating of megalopolis ecology state by means of evaluation of green plant state is described in the article. Together with Megalopolis Ecomonitoring and Biodiversity Research Center of National Academy of Sciences of Ukraine there were got results of experimental researches of influence detecting of heavy metals and harmful substances on the trees and plants in Kiev.

Keywords: Virtual Laboratory; Computer-Aided Design; Access Methods; Distributed System, Kautsky effect, chlorophyll, chlorophyll fluorescence induction, fluorescence, fluorometer, portable device, ecology.

ACM Classification Keywords: J.6 Computer-Aided Engineering –Computer-Aided Design (CAD); D.4.3 File Systems Management – Access Methods; K.4.3 Organizational Impacts – Computer-Supported Collaborative Work; J.3 Life and Medical Sciences - Biology and Genetics, J.7 Computers in Other Systems – Real Time, C.3 Special-Purpose and Application-Based Systems – Microprocessor/microcomputer applications

Introduction

Fast spreading of market relations and competition between manufacturers of different (including scientific) production and information services makes very actual the acceleration of development of theory and methods of computer-aided design of computer devices and biosensors. Actual design of devices and systems, which is often used, needs a lot of time, material, and human resources. If one needs to make a small set of devices by means of actual design, the price of final production becomes very high. Therefore, manufactures of computer devices get very complicated issue, which consists in time and price reduction of new devices design. Only after solving of this issue the new devices of own design will be able to become competitive on domestic and world markets.

To minimize these design expenses to reach high level of competitive recently side by side with actual design it is begun to use a virtual design. These methods realized by means of virtual laboratories of computer-aided design (VLCAD), which are based on advanced access methods and worth to be used on the stage of the requirements specification or EFT-stage, because it gives the possibility of fast estimating of the project realization, certain characteristics and, as a result, expected benefit of its applications.

Market analysis and joint discussion confirm the acute necessity in the developing of new virtual design methods and in the creating on their base open VLCAD, main feature of which is possibility to use such remote laboratory by specialists in different science branches, without education in information technologies and instrumentation.

Preconditions and Main Principles of Virtual Laboratory Creation

One of problems, which are met by developers of new devices for different fields of science and engineering, is existence of more than 15 thousands of such fields or disciplines to date. Naturally to carry out researches or create a new device developers must have knowledge from disciplines, which refer to developed device. Therefore it is important to orientate new computer technology for interdisciplinary researches, which occur on boundary of several science fields or disciplines.

Urgency of these researches is caused by absence of computer technology of smart devices designing for interdisciplinary researches in Ukraine and Bulgaria. It does not allow to test on computer models the performance of designed devices, which are created on the base of new effects or sensors. To date to develop new device or to check the possibility of its creations and operation it is necessary to invite specialists in information technology, electronics and circuit technology on the commercial base. Getting results in such way is very expensive and, as usual, is not supported with necessary funds. This again confirms acute necessity of design technology development and creating on their base the open virtual laboratories, the main feature of which is possibility to use these virtual laboratories by specialists from different science fields, especially non-specialists in the field of information technology and instrument making.

Good solution of this problem is to create on the base of information technologies the special hardware-software tools [Palagin and Sergiyenko , 2003], which in convenient mode (for example, with help of dialogues) allows sensor developer to check possibility of creating of new devices and the device model. Such tool has to give possibility to create a model set of certain device (e.g. functional, electrical, operational etc.), including prior parameters calculations, project of circuit board and set of design documentations (e.g. cost, performance, validity, size, reliability etc.). Description of sensor or its model should be incoming data for such design system.

Now on the world market there are a lot of software for computer-aided design (CAD), which allow to automotive design of new devices and systems and analyze them in different ways [Gavrilov, 2000]. But for skilled usage of such CAD software it is necessary to have special skills in circuit technology, electronics and instrument engineering, and also know this CAD software perfectly. It is clear, that sensor developers, who are mainly chemists, biologists, biochemists, physicists etc, have no enough possibility and skills to use such complicated CAD software for designing of new devices on basis of developed sensors. In such case they need help of CAD specialists. But it is very expensive service. Therefore in most cases sensor developer leave sensor "in quiet" and switch his attention to another tasks.

It is necessary to note, that only by paying attention to the design process of computer devices it will be possible to reach a high level of competitiveness of scientific developments, what lets in the future to take up notable place on the world market. It is easily to see, that most devices have the same structure, to be exact, they consist of sensor, measuring channel, data processor, interface and additional subsystems. That's why process of designing could be easily formalized.

To solve this problem within the bounds of international Ukrainian-Bulgarian project it is began developing of virtual laboratory for computer-aided design for computer device designing [Palagin et al, 2007]. The VLCAD is being created on the virtual methods of design [Galelyuka, 2008]. Offered virtual laboratory are created on the base of formalized representation of theoretic knowledge, principles of organization, methods and facilities of computer-aided design and testing information-measuring systems and devices, in particular on the base of subject field ontology. For VLCAD creating it is used the methodology of system integration [Palagin and Kurgaev, 2003] concerning base methods and tools, on which it is created. In the methodology basis it is putted system approach to tasks of analysis and synthesis of both VLCAD component and object of designing, and, first of all, forming knowledge system of interdisciplinary nature and its computer ontology. Proposed VLCAD is open system.

Mentioned VLCAD allows sensor developer to:

- check possibility of creating of devices and computer facilities (including portable devices) on basis of developed sensors without involving specialists in circuit technology and instrument engineering at the stage of EFT-project. It allows reducing terms and costs on this stage;
- avoid expensive actual tests on the stage of device creating by replacing with virtual methods of designing and testing;
- prepare set of design documentations on designed device in the automotive mode without involving corresponding specialists. Next stage is to send design documentations to contract production for creating of test party of devices.

Terms "Virtual laboratory" and "Virtual design" appear lately, so, as usual, they are absent almost in all dictionaries. The word "Virtual" appeared in word literature a long time ago. "Virtuality" has almost all features of empirical reality with the exception of its direct presence. So, it is "reality, which is absence" or "present absence". Also, "virtual" is one, which has no physical embodiment. "Virtual reality" is comprehended as a part of reality, which is modeled by computer device. Since any laboratory is a part of reality, so taking into account above-stated, there can be formulated next term of "virtual laboratory": virtual laboratory is imagined laboratory, which has all features of real laboratory and is modeled by means of software and hardware.

In general, virtual laboratory is some information environment, which lets to conduct researches in the case, when there is no direct access to test subject. Researches can be conducted by means of mathematical models and with using of remote access to test object.

Somebody may work with physical objects in two ways:

- emulation of physical objects with defined level of approximation to reality;
- remote access to physical objects with defined capabilities of interacting.

The first method lets to get completely virtual analog of some environment, what is very practical. Disadvantage of this method is complexity of model creating, which is very approximate to reality.

The second method provides maximal approximating to reality. But it requires creating and supporting of remote access to test objects, but the number of access channels is limited. Server of laboratory setup, besides access to equipments, is able to give background and methodological materials to researcher. Remote experiment in most cases is conducted in such way. Researcher communicates laboratory setup server and send data for experiment. Server software conducts experiment and sends results as tables, graphics to researcher.

For realization of VLCAD it is decided to use the first method. But the second method is not set aside and in future it will be probably used as additional tool.

Virtual laboratories, in which experiments are conducting by means of mathematical models, differ from previous one by using mathematical or other model instead of real test object. These laboratories have no laboratory setup.

Creating of VLCAD

Before VLCAD creating, first of all, it is necessary to determine features of VLCAD as tool for interdisciplinary researches and what functions it has to have.

In general, VLCAD is a system for computer-aided design, but with certain difference. This difference is that for using any CAD system it is necessary to have deep knowledge in this software, instrument engineering, circuit technology and electronics. It is expected, that for using VLCAD users need only experience in work with computer. Design process by means of VLCAD is much regulated and is going on dialog mode with additional help messages. So, the main feature of VLCAD as tool for interdisciplinary researches is orientation of this system in the side of usual users, which are nospecialists in the field of information technology, instrument engineering and circuit technology. It make practicable to develop new device or verify possibility of such development by such specialists, as biologists, ecologists, medics, biochemists at el.

For such VLCAD creating, first of all, it is necessary to execute next actions:

- improve design process on the base of using mathematical methods and computer tools [Palagin et al, 1993];
- automate process of searching, processing and issuing of information;
- use methods of optimal and variant designing, effective mathematical models of design object, components and materials;
- create multi-dimensional hierarchical databases with integrated data of reference type, needed for computer-aided design;
- improve quality of designed document execution;
- increase creative part of designer work at the expense of automation of noncreative routine work;
- unify and standardize design methods;
- train specialists, including students, masters etc.;
- implement interaction with automatic systems of different levels and purposes.

To define place of VLCAD in the design process it is necessary to take into account world experience of design engineers of computer and portable devices. Integrated scheme of design process with proper outlet documentation and the place of VLCAD in design process are shown on Fig. 1. As one can see, VLCAD covers early stages of designing.

Since VLCAD has many features of CAD system it is rationally to use methodology of CAD system creating during VLCAD developing, but taking into account features of VLCAD. It is necessary to note, that now there are several conceptions of CAD system creating. Full-automatic and man-machine systems are the most widespread. First systems are difficult to build and, in some cases, it is impossible to create such full-automatic system, because design process is heterogeneous, has many internal and external connections and includes a lot of undefined factors. To take into account these undefined factors it is necessary to use creative opinion of designer.

Taking into account described above we can state, that creating of VLCAD for computer device design is very important scientific-technical problem, and implementation of such VLCAD needs certain investment. Received experience and analysis of world literature let us to separate out next main principles of such virtual laboratories creating:

1. Virtual laboratory is man-machine system. All design systems, which had been developed and now are being developed, are computer-aided, and designer is the main part of these systems. Human in such systems has to solve tasks, which cannot be well defined, and problem, which human by using own heuristic abilities may solve better and more effective than computer. Close interaction between human and computer during design process is one of principles of development and exploitation of any CAD systems for computer device designing.

2. Virtual laboratory is hierarchical system, which use comprehensive approach to automation of all design levels. Level hierarchy is presented in system structure as hierarchy of subsystems.

3. Virtual laboratory is set of informational-concerted subsystems. This very important principle refers not only to connections between large subsystems, but to connections between separate parts of subsystems. Informational compliance means, that almost all possible sequences of design tasks are served by informational-concerted programs. Two programs are informational-concerted if all data in these programs are part of numeric arrays and do not need transformations during sending from one program to another and inversely. So, results of one program can be incoming data for another program.

4. Virtual laboratory is open system, which are permanently expanding. Permanent progress of technology, designed objects, computer technology and computational mathematics lead to appearance of new, more perfect mathematical models and programs, which replace old analogs. So, VLCAD has to be open system and be able to use new methods and tools.

5. Virtual laboratory is specialized system with maximum using of unified units. Requirements of high efficiency and universality for any system are, as a rule, conflicting or competitive. It is reasonable to develop VLCAD on the base of unified parts. Necessary condition of unification is searching of common principles in the modeling, analysis and synthesis of technical objects.

Computer technology, what are offered by us, is hardware-software complex, what consist of personal computers or work stations with set of necessary peripheral items, connected in local and worldwide networks, such as Internet, and is supplied with all software. Using of these technologies already increase automation level of design stages of new devices for different purposes, including devices for interdisciplinary researches.

Today such complex systems, as VLCAD and CAD, are developed as knowledge-oriented systems, main feature of which is informational integration. Informational integration is the main application area of ontology using. Ontology, as a rule, contains hierarchy of concepts of knowledge domain and describes important features of every concept by means of mechanism "attribute–value". Connection between concepts may be described by means of additional logical statements. Constants refer to one or several concepts. This and another ontology features let to use ontology in different fields of knowledge, increasing effect from application of different methods and modes of work with information or creating on their base new more effective methods [Palagin, 2005]. Especially efficiency of ontology application can be shown in such science intensive fields, as knowledge engineering and knowledge management, objects and processes modeling, databases designing, informational integration and data mining [Gladun, 1994].

Analysis of literature and certain application domain lets to specify requirements to ontology, on the base of which VLCAD is developing [Palagin et al, 2007], [Galelyuka, 2008]:

- Ontology has to include conceptual knowledge, but not episodic ones.
- Ontology has to be specified and internal concerted with structure, names and content for all defined conceptions.
- Ontology has to be structured and simple for understanding and searching of conceptions.
- Ontology has to be limited by certain application domain for defining of used conceptions. Ontology has not to include all possible information about application domain.

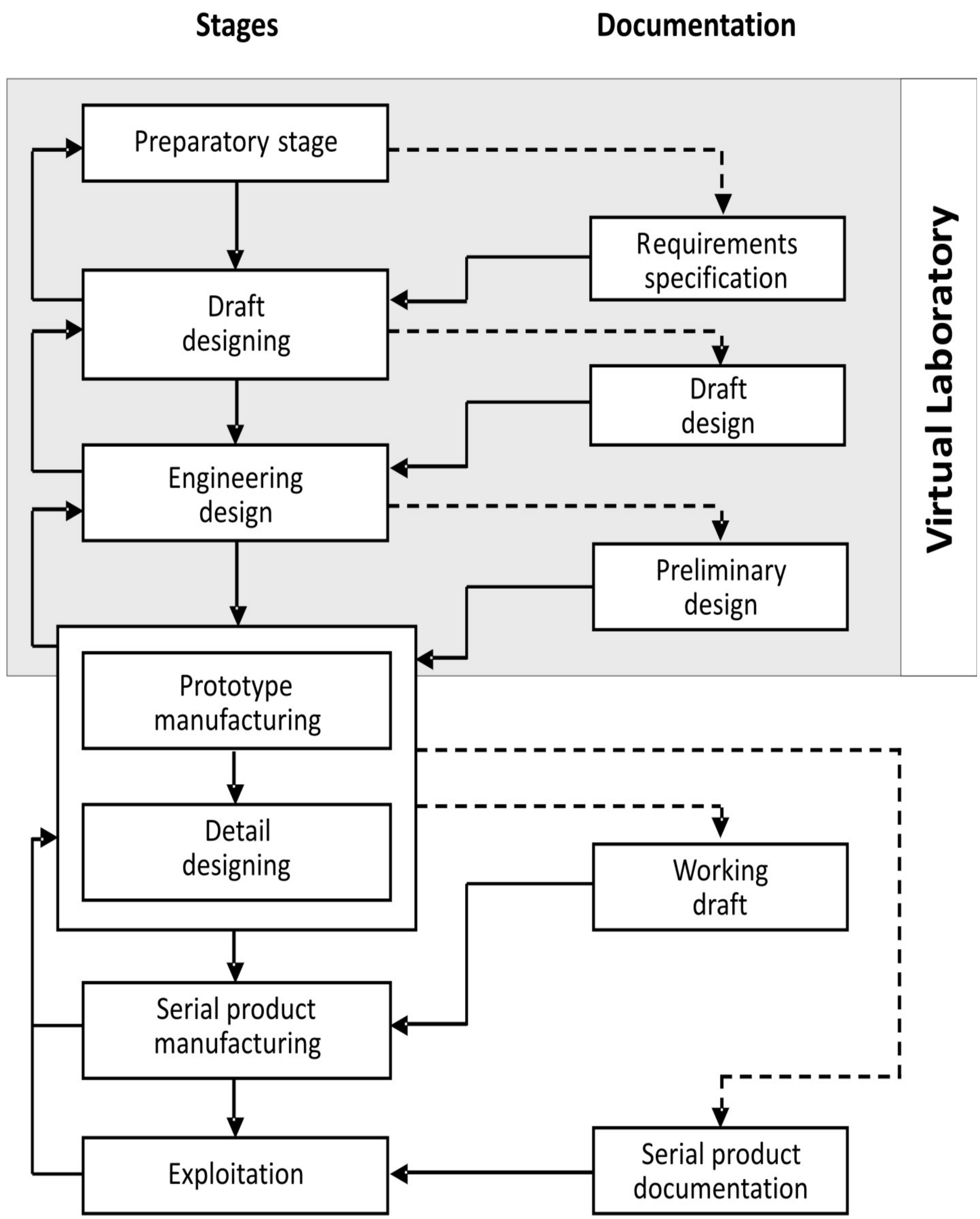


Fig. 1. Integrated scheme of design process with proper outlet documentation

VLCAD storage space

As a storage space for VLCAD a multi-dimensional access method, called ArM32, property of FOI Creative Ltd. may be used. It is built on the base of the Multi-Domain Information Model (MDIM) [Markov, 2004].

The ArM32 elements are organized in a hierarchy of numbered information spaces with variable ranges. There is no limit for the ranges the spaces. Every element may be accessed by correspond multidimensional space address given via a coordinate array.

The Multi-Domain Information Model (MDIM), presented in [Markov, 2004], is a step in the process of development of tools for data-base organization. Its main idea is to permit practically unlimited access to multi-dimensional information structures. In MDIM there exist two main constructs – numbered information spaces and basic information elements.

The Basic information element is an arbitrary long string of machine codes (bytes). When it is necessary the string may be parceled out by lines. The length of the lines may be variable. In ArM32 the length of the string may vary from zero up to 1GB. There is no limit for the number of strings in an archive but theirs total length plus internal indexes could not exceed the limit for the length of a single file of the operating system.

Basic information elements are united in numbered sets, called numbered information spaces of range 1. The numbered information space of range n is a set, which elements are numerically ordered information spaces of range n-1.

ArM32 allows using of information spaces with different ranges in the same archive (file).

The main ArM32 operations are reading, writing, appending, inserting, removing, replacing and deleting of a basic information element or any it's part.

The ArM32 numbered information spaces are ordered and main operations within spaces take in account this order. So, from given space point (element or subspace) we may search the previous or next empty or non empty point (element or subspace). In is convenient to have operation for deleting the space as well as for count its nonempty elements or subspaces.

ArM32 engine supports multithreaded concurrent access to the information base in real time.

Very important feature of ArM32 is the possibility not to occupy disk space for empty structures (elements or spaces). Really, only non empty structures need to be saved on external memory.

Using VLCAD for designing portable device "Floratest" for express-diagnostics of photosynthesis

Let remember, that only by paying attention to the design process of computer devices it will be possible to reach a high level of competitiveness of scientific developments, what lets in the future to take up notable place on the world market. It is easily to see, that most devices have the same structure, to be exact, they consist of sensor, measuring channel, data processor, interface and additional subsystems. That's why process of designing could be easily formalized. [Palagin et al, 2009]

An instance of using the VLCAD is designing the Portable Device "Floratest" as Tool for Estimating of Megalopolis Ecology State. Portable device "Floratest" is aimed for express-diagnostic of stress factors on plant state. It is developed in the V.M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine in the context of the program of Presidium of National Academy of Sciences of Ukraine (NASU) "Development in the field of sensor systems and technology" [Romanov et al, 2007]. The portable device measures chlorophyll fluorescence induction (CFI) without plant destruction. Using the curve of CFI (alike the cardiogram) allows diagnosing influence of one or other influential factor on the plant's state.

Party of this device is manufactured and transferred to organizations, worked in the agricultural sector, environmental protection area, mineral fertilizer production etc. for working out of methodical tools. Using of the device for estimating of megalopolis ecology state by means of evaluation of green plant state is described in the article. Together with Megalopolis Ecomonitoring and Biodiversity Research Center of National Academy of Sciences of Ukraine there were got results of experimental researches of influence detecting of heavy metals and harmful substances on the trees and plants in Kiev.

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 the portable device "Floratest" [Fedack, 2005, Palagin, 2007], which lets to estimate in several seconds the plant state after drought, frosts, pollution, herbicides etc. without plant damage. Like human cardiogram device builds CFI curve, which characterizes photosynthesis process, which is the base of plant vital activity.

It is possible to convert IFC curve in a description as a set of objects with features which values are integer numbers. The received description may be used by the system for inductive finding of regularities - Confor [Gladun et al, 2008], which permits to find common features of IFC curves for the trees which are under influence of equal oppresive factors. The found regularities may be used for automatic selection of harmful substances using the form of IFC curve.

In the process of designing of “Floratest” the VLCAD was used to:

- check possibility of creating of new modifications of "Floratest" on basis of developed sensors without involving specialists in circuit technology and instrument engineering at the stage of EFT-project;
- avoid expensive actual tests on the stage of device creating by replacing with virtual methods of designing and testing;
- calculate parameters (reliability, price etc.) of new device;
- prepare set of design documentations on designed device.

The sheme of using the virtual laboratory for designing of "Floratest” is shown on the fig. 2.

Principles of device operation

As a result of external influence, different objects, including biological ones, can generate plenty of radiation that is independent of these objects temperature.

All the types of radiation that were caused by some external sources of energy are called luminescence. Duration of luminescence after external influence stopping exceeds period of light fluctuations. Luminescence is conditioned by fluctuations of relatively small number of atoms or molecules of substance that become excited under energy source activity. Radiation is a result of transformation of atoms’ or molecules’ states into fundamental (unexcited) or less excited (they have less energy) states.

This is well adjusted with quantum theory, according to what every stationary orbit conforms to definite value of atom’s energy (Bore’s postulate). Being placed on stationary orbits an electron doesn’t radiate and doesn’t absorb electromagnetic waves. According to the second Bore’s postulate radiation and absorption can happen only when atom changes its state from one stationary state to another:

$$h\varpi_{mn} = h\nu_{mn} = E_n - E_m \quad (1)$$

where ϖ_{mn} or ν_{mn} – photon’s frequency, E_m, E_n – energy values of the states m and n, h – Planck's constant, m and n – the numbers of energy states. At the same time electron switches from one stationary orbit to another.

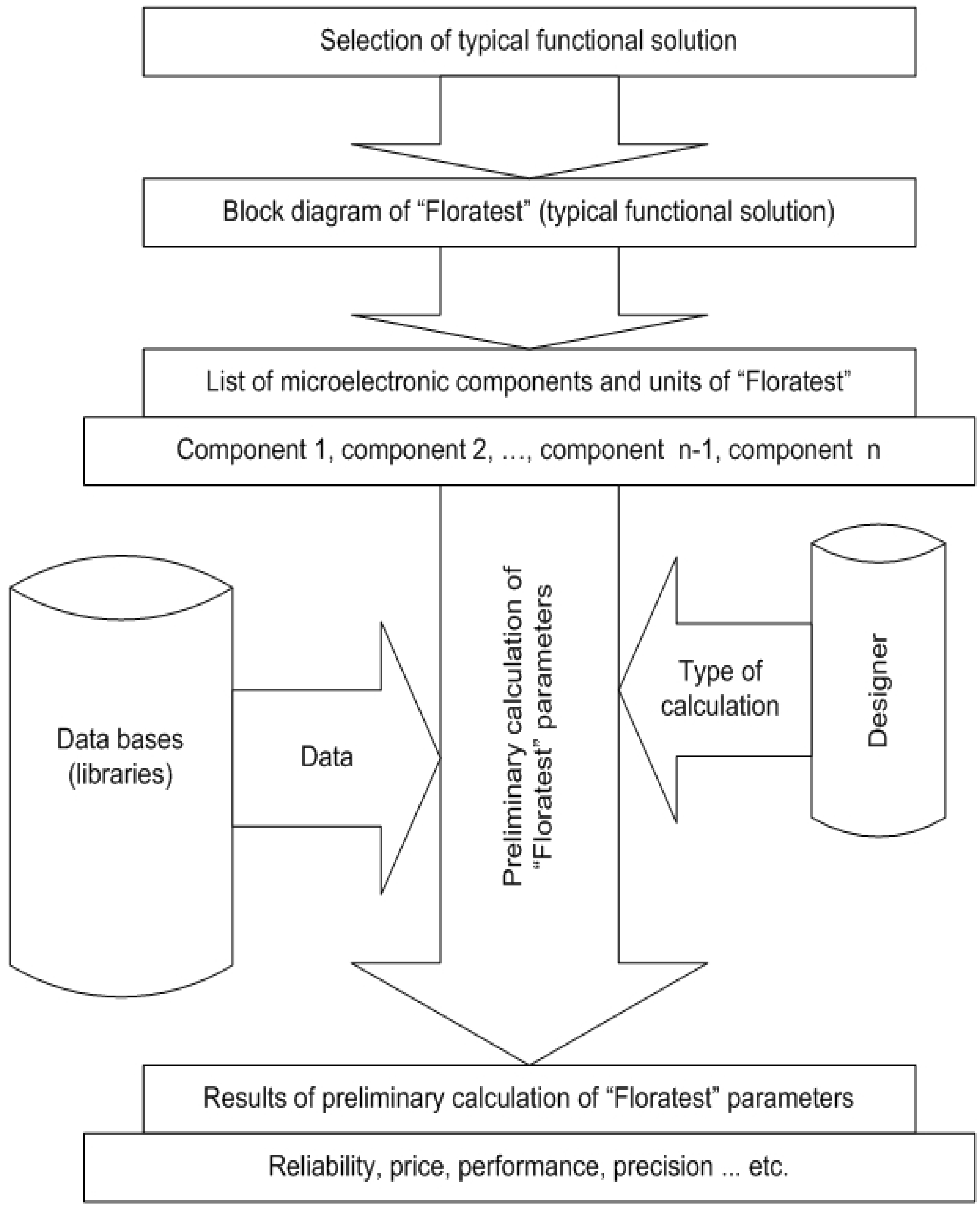


Fig. 2. Designing of "Floratest" by means of virtual laboratory

Luminescence is defined by the structure of substance energy spectrum, the average time of staying in excited states and rules of selection, which allow absorption or radiation of light of defined frequency. Short-timed luminescence is also called fluorescence. Luminescence which appears during lighting of substance (phosphor) with visible or ultraviolet light is called photoluminescence. Usually process of luminescence satisfies Stocks' rule that claims that wave length λ' of radiated light is greater than wave λ of excited light. According to the quantum theory this means that photon's energy $h\varpi(h\nu)$ is used partially for non-optical processes:

$$h\varpi = h\varpi' + E, \varpi > \varpi' \quad (2)$$

where ϖ' – luminescence's frequency, E – energy waste on another process.

Luminescence is characterized by energy output which equals to ratio of luminescence energy to energy that was absorbed by substance under stationary conditions.

Energy efficiency of photoluminescence increases proportionally to wave length λ of absorbed light up to the definite maximum value at $\lambda = \lambda_{\max}$ and then rapidly decreases to zero at $\lambda > \lambda_{\max}$ (Vavilov's rule). A sharp decrease of energy at $\lambda > \lambda_{\max}$ is explained by the fact that at these wave lengths λ the energy of absorbed photons is not enough for the process of phosphor atoms and molecules transfer to the excited states.

Ratio of luminescence photons number to absorbed photons with fixed energy is called quantum yield of photoluminescence. According to Vavilov's rule, which is under Stocks' rule, quantum yield of photoluminescence doesn't depend on wave length of excited light and rapidly decreases for anti-Stocks radiation.

Intensity of luminescence I depends on behavior of elementary processes that causes this radiation. In case of spontaneous luminescence, when radiation starts after light absorption during which atoms or molecules are transmitted to the excited level that is placed higher than the level at which radiation takes place and then these atoms (molecules) are transmitted to the luminescence level, intensity is subordinate to exponential rule

$$I = I_0 \exp(-t/\tau) \quad (3)$$

where I – lighting intensity at the moment t, I_0 – lighting intensity in a moment of excited radiation stopping, $\tau \approx 10^{-9} - 10^{-8}\,\mathrm{sec}$ – an average duration of excited state of phosphor atoms or molecules. Luminescence of compound molecules and phosphorescence (after lighting) of organic substance are subordinate to the low (3).

Under influence of light there can be happened photochemical transformation of substance (including photosynthesis), which is called photochemical reactions. In a process of such reactions light absorption takes place. Energy is spent on compound molecules and polyatomic ions decomposition to component parts and creation of compound molecules of primary ones. An example of photochemical reactions is decomposition carbon dioxide under influence of light

$$2CO_2 + 2h\varpi \rightarrow 2CO + O_2 \quad (4)$$

Carbon dioxide decomposition takes place in green parts of plants under sun light influence, as photochemical process, which is a part of photosynthesis.

One of the most important properties of the molecule of chlorophyll which is the basic pigment of plant cell is ability to fluoresce. For the first time this phenomenon was researched by Kautsky [Kautsky and Hirsch, 1931]. Dependence of chlorophyll fluorescence induction on time passed after start of lightning of plant's leaves is known as an induction curve or a chlorophyll fluorescence induction curve (Fig. 3). The form of this curve is rather sensible to changes in the photosynthetic apparatus of plants during adaptation to different environmental conditions. This fact is a basic for extensive usage of Kautsky effect in photosynthesis research. The advantages of the method of CFI are the following: high self-descriptiveness, expressiveness, noninvasiveness and high sensibility.

Abilities to estimate plants states using changing of Kautsky curve form are experimentally verified. So there are examples of changing form of this curve under influence external factors.

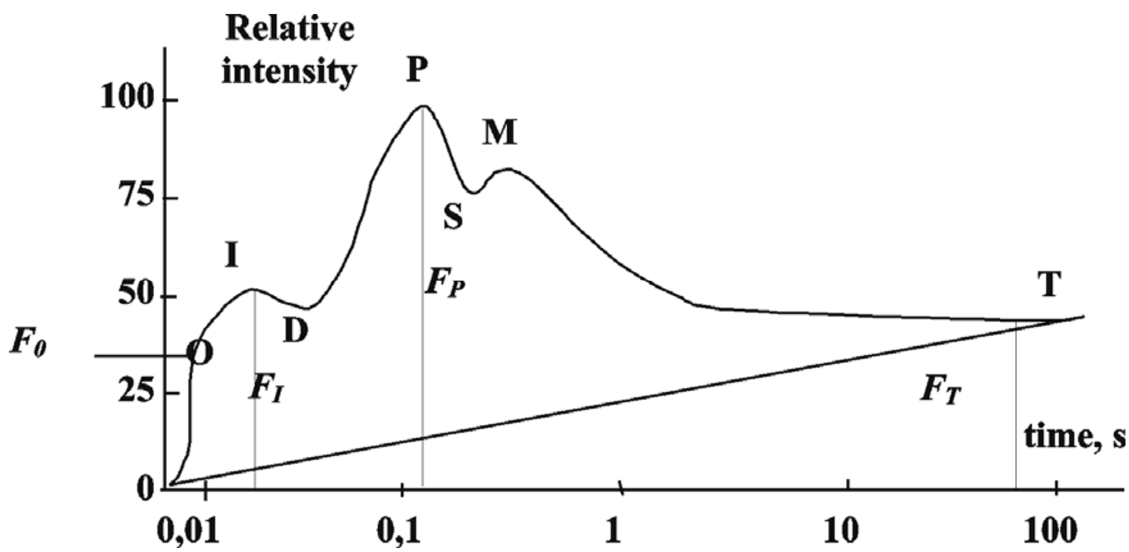


Fig. 3 Chlorophyll fluorescence induction curve

Increase of environment temperature relative to optimal for definite plant type causes decreasing of difference $F_V = F_P – F_0$. The reason is decreasing of activity of electron-transport chain or lighting activity of photosynthesis. During increasing of temperature to destruction level (45–50 °C), the level of intensity F_0 increases noticeable. It's possible to choose plants sort that are stable to high temperature influence using these parameters.

Decreasing of environments' temperature relative to optimal for definite plant type causes also decreasing of difference $F_V = F_P – F_0$, because of oppression of photochemical activity photosystem PSII. Ratio $(F_1 – F_0) / F_V$ is increasing. These features allow selecting cold-resistant plants.

Salinity of ground results in decreasing of level of F_P and F_0. Ratio $(F_P – F_0) / F_P$ is decreasing. Reason of that is oppressing of photo system PSII activity. Using these features it's possible to choose plants that are stable ground salinity.

Water deficit results in decreasing of subtraction $F_P – F_0$ in direct proportion with decreasing of water potential of leaf. Most probable reason is slowing down of photo system PSII recovery of primary acceptor because of oppression of excretion oxygen and intersystem transport of electrons.

Device features

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 IFC curve, which refer to separate areas of photosynthesis chains as diagnostic features. By IFC curve form it is easily to detect influence of one or another factor on the plant state.

Appearance of portable device "Floratest" is shown on the Fig. 4.

Fig.4. Appearance of portable device "Floratest"

Application areas of portable device for express-diagnostics of plant state:

- express-estimating of 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 of precision agriculture technology for increasing the quality of agricultural products;
- using of the device in the insurance agriculture to get predicted results of future yield;
- automation of researches in the plant physiology field.

Functional diagram of the device is shown on the Fig.5. Data processing unit and displaying unit are built on the base of microconverter ADuC842 and graphical display with resolution capability of 128*64 pixels. Microconverter is system-on-chip for data acquisition and processing, which includes analog-digital and digital-analog converters, reference supplies, temperature sensor, timers, power supply monitor, embedded industry standard 8052 microcontroller, external and internal data memory, program memory etc.

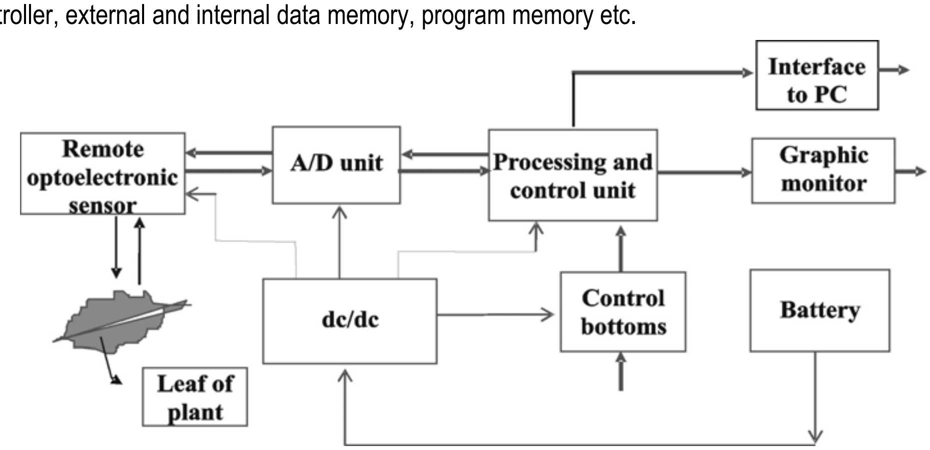


Fig.5. Functional diagram of portable device "Floratest"

Remote optical sensor is built as "reflection diagram" on the base of four light-emitting diodes and one photodetector. "Reflection diagram" means that light-emitting diodes and photodetector are situated from the same side of researched leaf. To research chlorophyll fluorescence in the red spectral region the filter is placed on the input of photodetector. Emission intensity of light-emitting diodes and photodetector sensitivity can be changed during measuring process. Integrated algorithm of device work is shown on the Fig.6.

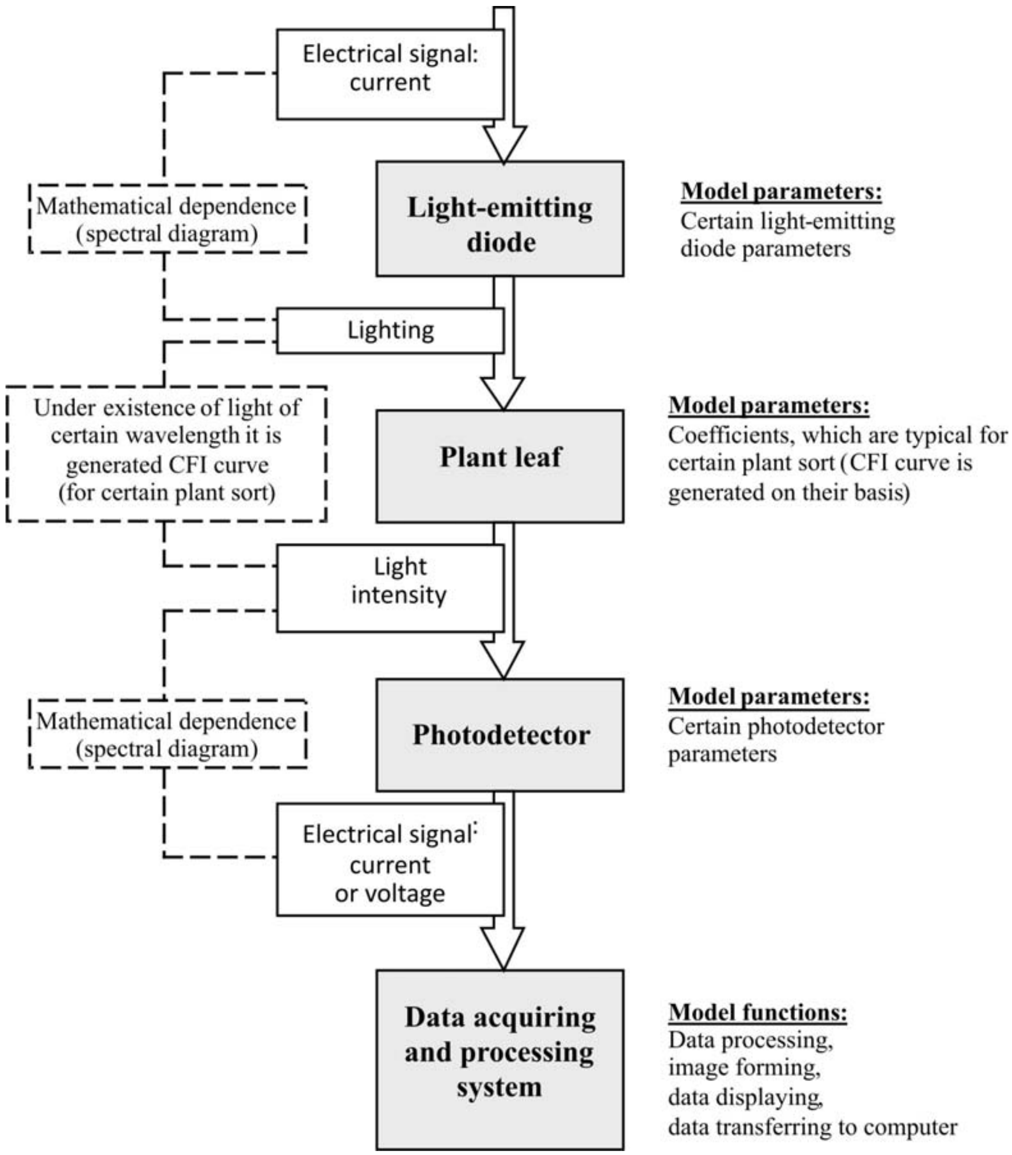


Fig.6. Integrated algorithm of device work and proper models

Today it is not enough to acquire and save measurement result in the portable device memory. It is urgent to transmit measurement results from places of measurement to laboratories or centers of operative estimation of condition and necessary decision making. For data transmitting from measuring channel to receiving point it is proposed to use mobile communication by means of midget GSM-unit with GPS-subsystem, which is embedded in the portable device, and GSM-modem, which is connected to computer or work station. During such measurements the transmissions of a small amount of data are required, so it is reasonable to use GPRS standard. Data acquiring, processing and transmitting system on the base of portable device with radio channel is shown on the Fig.7.

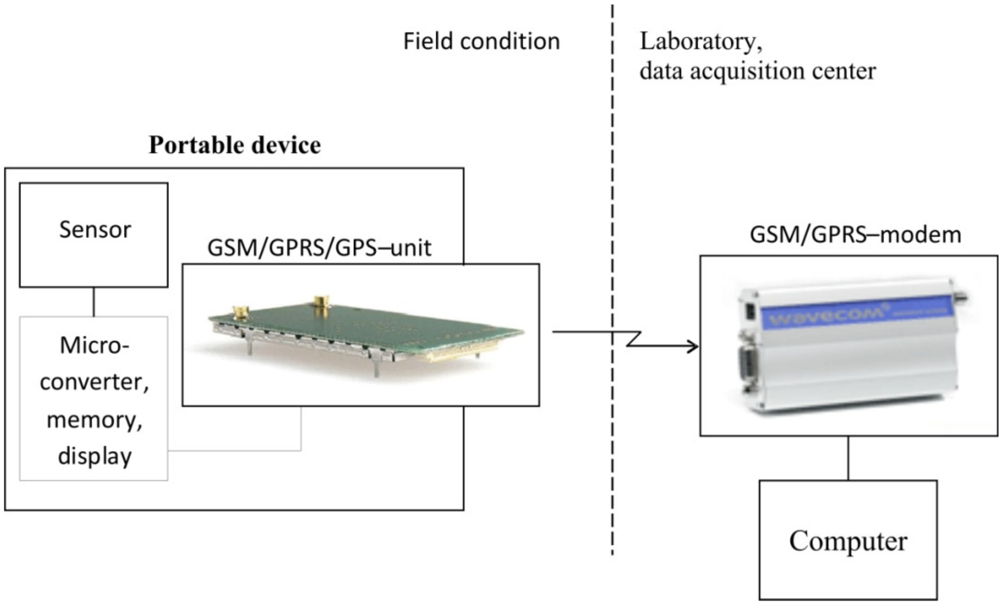


Fig.7. Data acquiring, processing and transmitting system
on the base of portable device with radio channel

Device application

The experimental researches of the "Floratest" were conducted in National Scientific Center "V.E.Tairov's Institute of viticulture and winemaking" of Academy of Agrarian Sciences of Ukraine.

Examples of the practical usage of fluorometer "Floratest" in the National Scientific Center "V.E.Tairov's Institute of viticulture and winemaking" are shown on Fig.8 and the graph of CFI on the device display are shown on Fig.9.

Fig. 8. The sensor of the "Floratest" on the vine leaf

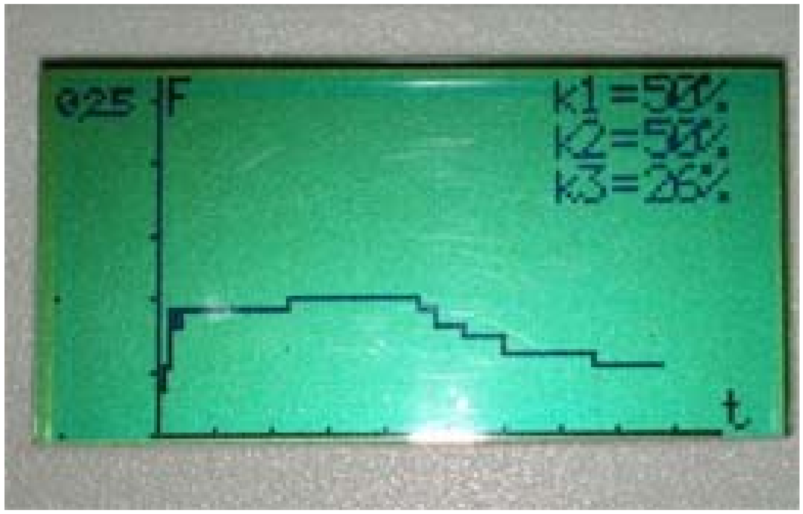


Fig. 9. The image of CFI on the device's display

The conditions and results of the experimental researches are listed below.

Mature leaves of vine were used in the researches. Under changes of soil watering conditions there were observed sharp changes in behavior of induction transitions of chlorophyll fluorescence which were accompanied by quite essential changes of leaf tissue spectral characteristics.

Determination of fluorescence spectral characteristics was done by placing the device's sensor on the leaf's surface without integrity disturbance directly in a pot or in a field. It allowed to research on plastid and vacuolar pigments in their natural state and in that way approaching to understanding of the biophysical and physiology-biochemical processes which take place in the live leaf, and determination of important sides of photosynthetic activity.

Fluorescence intensity of the sample was determined in relative units.

It is significant that under natural conditions in the middle latitudes the drought is accompanied simultaneously by high temperatures of air, and that intensifies bad influence of ground water lack on agricultural plants.

Even in the first variant of experiment (drought) there appeared considerable changes of the behavior of fluorescence induction comparing to the control samples. Changes show in weakening of penetrability of the chloroplasts' membrane structures. That results in substantial increase of time characteristics of fluorescence induction slow decrease. At the same time noticeable variety differences become apparent. Sharp decrease of its value is typical for profound functional injuries of photosynthetic structures and cells of particular variety entirely.

Accordingly in this stage of drought influence significant variety differences in exsiccate factor resistance of both photosynthetic structures and lamina's parenchymal cells entirely became apparent.

More deep changes of destructive nature may be observed in case of high temperatures (+40 C), which influence on leaves complementary to drought. In this case for all the varieties being studied significant and almost irreversible functional changes of plastid structures are noted. These functional changes show in sharp decrease of CFI intensity.

Disastrous changes of life activity of vine leaf cells which take place during these processes show in oppression of biosynthetic processes, intensive decomposition of cytoplasmic structures and intensification of oxide catabolism of plant cell's content. The consequence of these processes is decrease of CFI intensity as a result of its oxidizing transformation.

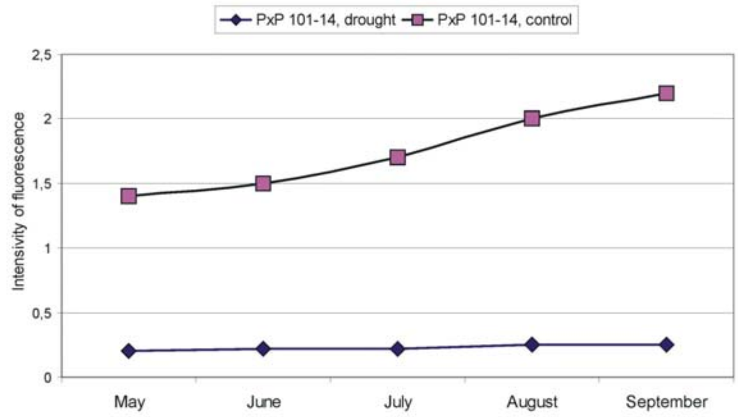


Fig. 10. CFI intensity of vine plant (sort PxP 101-14) under drought and normal conditions

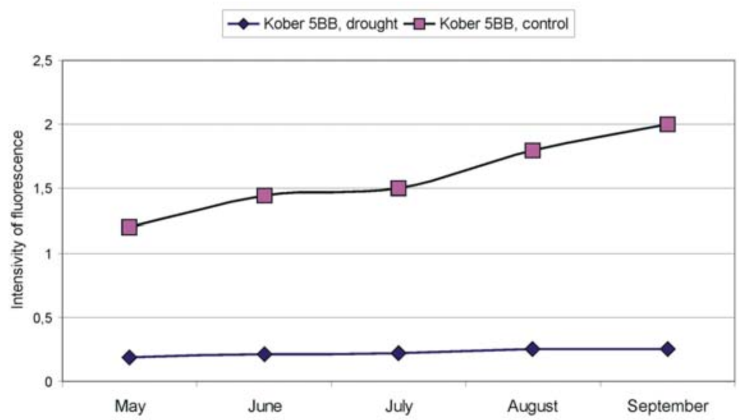


Fig.11. CFI intensity of vine plant (Kober 5BB) under drought and normal conditions

On the Fig. 10 0and Fig. 11 there are shown the diagrams of measuring of chlorophyll fluorescence intensity for two sorts of vine plants (PxP 101-14 and Kober 5BB) during 5 months. The vine plants were under drought influence and normal conditions.

Thus, a water deficit shows up on the Kautsky curve as difference of fluorescence ($F_p – F_0$) decrease. The most credible reason of this is oppression of oxygen emission which is related with slowing down of electrons transfer. Assuming that F_0 almost does not change for the test and control plants, in a maximum point the chlorophyll fluorescence intensity value can define the level of water deficit.

In 2008 together with Megalopolis Ecomonitoring and Biodiversity Research Center of National Academy of Sciences of Ukraine experimental researches of portable device "Floratest" were carried out to detect influence of heavy metals and harmful substances (e.g. lead, sodium, chlorine etc.) in leaf and soil on the plants state in Kiev. Today long-term phytomonitoring methods are used. They consist of visual observations and chemical analysis of soils and plant fragments and needs complicated equipments and lasts more than one week.

Long duration and complexity of existing methods of heavy metals and harmful substances detecting in live plants and necessity to involve skilled specialists to perform these researches set necessary conditions to develop special diagnostic methods and tools for this aim. Preliminary researches indicate that portable device "Floratest" can be used for detecting of heavy metals and harmful substances influence on state of plants by measuring of CFI curve. The form of CFI curve changes versus level of harmful substances influence.

Joint researches were carried out in Kiev green regions by means of common phytomonitoring methods and portable device "Floratest". After processing of research result there were built dependences for searching correlations between chlorine content in trees' leaf, which are got by common phytomonitoring methods (Figure 12), and readouts of portable device "Floratest" (Figure 13). Even one can see some dependence between chlorine content in trees' leaf and readouts of portable device "Floratest" (stationary region of IFC curve). Calculations, made by mathematical methods, show certain correlations between these values. Such researches were made for other harmful substances, such as sodium, magnesium.

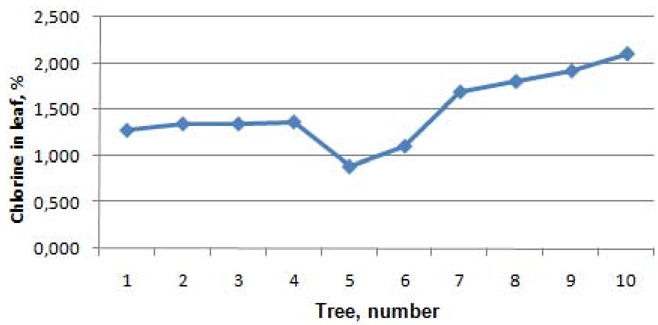


Fig. 12. Chlorine content in researched trees' leaf

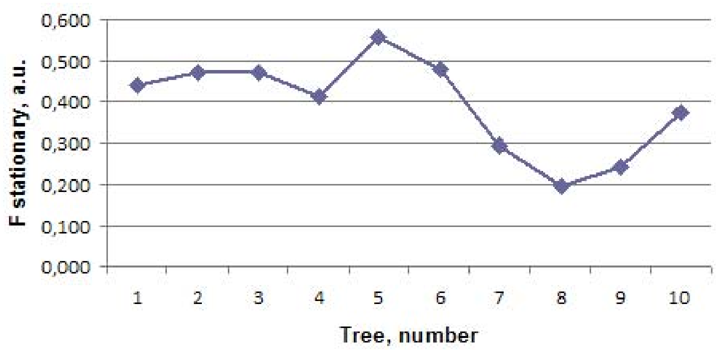
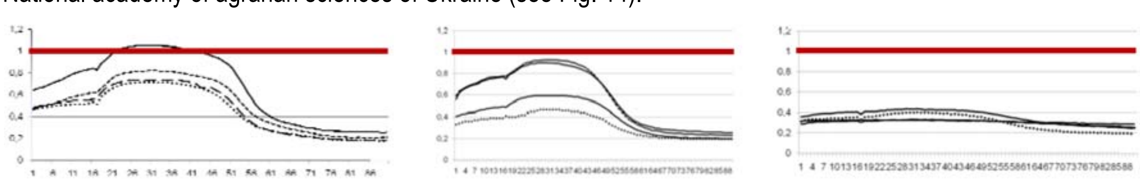


Fig. 13. Readouts for researched trees

It is easily to concede that IFC curve form expresses not only contents of separate harmful substance, but general state of tree versus influence level of harmful substances.

Researches of developing smart biosensor device "Floratest" for detecting of water deficit of plants were executed in the National scientific centre "Institute of viticulture and wine-making named after V.Ye. Tairov" of National academy of agrarian sciences of Ukraine (see Fig. 14).



(a) before predrying (b) after 10 hours of predrying (c) after 24 hours of predrying

Fig. 14. Measuring chlorophyll fluorescence induction curve

Conclusion

For increasing of competitiveness of science products it is necessary to develop new hardware-software tools, what is applicable for using in interdisciplinary researches. Virtual laboratory for computer-aided design can serves as example of such tool. In the article it is considered preconditions and main principles of such virtual laboratories creation, main purpose of which is to give possibility for sensor developers to verify ability of creating new devices on the base of their sensors on the early stages of designing, particularly on the stage of requirements specification or EFT-stage.

The features of ArM32 are appropriate for building the information base of VLCAD. The multi-dimensional information spaces make possible the effective creating of complex information structures using small amount of resources which is very important for VLCAD. At the first place the ontology's' representing and knowledge formation processes as well as intelligent recognition and classification are realizable.

An instance of using the VLCAD is designing the Portable Device "Floratest" as Tool for Estimating of Megalopolis Ecology State. Portable device "Floratest" is aimed for express-diagnostic of influence of stress factors on plant state. It is developed in the V.M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine.

The portable device measures chlorophyll fluorescence induction without plant destruction. Using the curve of chlorophyll fluorescence induction (alike the cardiogram) allows diagnosing influence of one or other influential factor on the plant's state. On basis of preliminary researches there were shown that using of portable device "Floratest" let to detect in express mode the worsening of photosynthetic apparatus of plant by measuring fluorescence of native chlorophyll on the early stages. During experimental researches, there were developed methodical tools, which allow evaluating the state of vine plants under drought conditions and conditions of insufficient water capacity in express-mode.

Using VLCAD the design process has been facilitated. The possibility to convert IFC curve in a description as a set of objects with features which values are integer numbers allows implementing the intellectualized components in the design process as well as in the real usage of the "Floratest".

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