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INTELLIGENT SYSTEM AND EQUIPMENT FOR GREENHOUSES MONITORING

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Abstract

Greenhouses are one of the interesting and important parts of agriculture. Industrial greenhouses are used for growing of large amount of vegetables, fruits and flowers. Individual greenhouses usually have small sizes and are used as hobby of people for growing different, sometimes exotic plants. For correct growing of plants is necessary to ensure special conditions as soil moisture, room lightening, soil, air temperature, and so on. In the case of industry greenhouses, the monitoring process usually is provided by a control system and operator, who regulates necessary conditions. In the case of individual greenhouse usually is difficult to obtain required growing conditions due to impossibility for individual person to be always next to the greenhouse. For solving of this problem can be used network system and special equipment, placed into the greenhouse.

Proposed greenhouse represents a modular system, which consists of separate planters that are essentially links of one whole chain. Planter is equipped by all necessary components for ensuring required growing conditions. Main of them are heating, watering, and lightening systems. On the bottom of planter a heating cable is installed so that it does not disturb the water drainage. Excessive moisture simply flows out from the planter along inclined floor. Soil watering is done by nozzles placed on the front and back walls of the planter. Both ends of watering tubes can be joined to general watering system by threaded components. Plants lightening is made by lamp places in the planter top. Required light intensity can be ensured by different lamp types. Planter local electrical and watering systems can be simplicity joined to local systems of other planters and to greenhouse system as a whole. Separate planters usually are used for growing of defined types of plants. Generally, all necessary parameters can be controlled by monitoring system but some of them will be obtained by planter controller and some by greenhouse controller. Air temperature and moisture covers larger space than area of one separate planter and should be monitored by greenhouse measuring system. Soil electro-conductivity and acidity do not change abruptly and intensely and can be measured twice in the season by portative devices. Main parameters, light intensity, soil moisture and temperature are measured by sensors installed into planter. Measuring frequency can be some seconds and even milliseconds but for plants growing process it is not necessary to measure these parameters more often than once an hour or once a half of hour.

Main component of communication system is a global cloud server where a constantly updated database is held, which contains parameters of growing conditions and recommendations. Greenhouses and planters have IP addresses and can be separated in the global system. Planter controller periodically measures plant lightening, soil moisture and temperature by installed sensors. Greenhouse controller reads this information from all planters into the greenhouse and also measures air temperature and moisture by sensors. Server periodically reads this information from all greenhouses in the cluster, compares with required values and if it will be some deviations from norm sends a command to the greenhouse controller. The user (greenhouse owner) is able to receive the current state of all necessary parameters from the server by smartphone. In addition, he is able to change default values of growing conditions for its own greenhouse or separate planters.

Main result of this research is creation of a global monitoring system. Database is created on base of fifteen types of plants and can be flexible expanded. System proposes to customer information about validated planter and conditions for its good growing. For online monitoring server periodically communicates with greenhouse microcontroller. Costumer can get information by SMS or 4G connections.

Key words: *Vegetables, Fruits, Plants, Greenhouse, Monitoring.*

1. Introduction

Monitoring systems and network solutions are currently widely used in agriculture for different functions. Sergeev *et al.,* [1] considers monitoring of food security and safety. Stevanovski *et al.,* [2, 3] uses these opportunities for agribusiness development. Automatic control and network applications are used for improvement of fruit and vegetables quality (Meyer [4], Brosnan *et al.,* [5], Blasco *at al.*, [6], Dara *et al.,* [7]). Usually these methods are applied for industrial solutions (GGS Structures [8], and other) but it is useful to use them for individual gardens and greenhouses (Heikkinen [9], and other).

Greenhouses are one of the interesting and important parts of agriculture. Industrial greenhouses are used for growing of large amount of vegetables, fruits and flowers. Individual greenhouses usually have small sizes and are used as hobby of people for growing different, sometimes exotic (Özbek [10]) plants.

For correct growing of plants is necessary to ensure special conditions (Karadeniz [11, 12]) as soil moisture, room lightening, soil, and air temperature (Schwarz *et al.,* [13]) and so on. In the case of industry greenhouses, the monitoring process usually is provided by a control system and operator, who regulates necessary conditions. In the case of individual greenhouse usually is difficult to obtain required growing conditions due to impossibility for individual person to be always next to the greenhouse. For solving of this problem can be used network system and special equipment, placed into the greenhouse.

One effective solution for greenhouse building can be implemented by using separate boxes (planters) for plants growing. Since different plants need different growing conditions it is simple enough to ensure this by placing of plants into separate planters. Some plants cannot grow next to each other and this problem can also be solved. However, the most important problem is monitoring and ensuring necessary growing conditions that can be simply solved with using of special equipment.

This research considers design of network structure and communicating procedure between global server, individual greenhouses and separate planters for plants growing. It is shown common design of the planter taken into account ensuring necessary conditions for plant growing. As base parameters are considered air and soil temperature, lightening and soil moisture but the system can be extended with adding some other parameters.

2. Materials and Methods

2.1 Planter

Greenhouse represents a modular system (Figure 1), which consists of separate planters (Figure 2) that are essentially links of one whole chain. Planter is equipped by all necessary components (Tanjuhhin [14]), for ensuring required growing conditions. Main of them are: heating, watering, and lightening systems the analysis of that is presented in the Table 1.

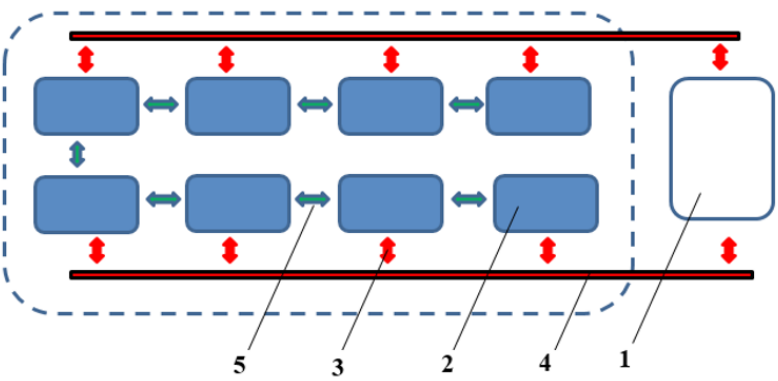

Figure 1. Scheme of the base idea of smart greenhouse:
1 - central controller; 2 - planter, 3 - data flow from/to the planter, 4 - wires, Wi-Fi, 5 - hoses, electricity

Table 1. Conventional systems used in greenhouses

System type	Solution	Description	Advantages	Main limitations
Heating system	In-floor heating	Installation of heating pipes directly inside concrete floor	Providing uniform heating to the entire crop Maximizes growing area	Fived structure without the ability to access the piping Need for separate heating/pumping system for water circulation
	Overhead heating	Installation of heating elements above the plants	Protection from cold night temperatures Snowmelt system can be integrated	Need for rigid structure to fix the equipment High initial investment
	Under bench heating	Installation of heat pipes below the raised benches	Uniform temperature in the root zone Air temperature in greenhouse can be set to lower	Necessity to build special benches Separate heating/ pumping system
	Regular cable/pipe heating	Installation of heating cable/pipes under the layer of planting soil	Direct transfer of the heat from the heating element to the soil	Inability to access the cable/pipes without removing the soil or plants
Watering system	Drip irrigation	Watering pipes with drippers installed directly near the plant	Maximum use of available water Soil erosion is eliminated	Necessity to occupy growing space with piping Small watering area coverage
	Mist/Sprinkler irrigation	Watering pipes with misters are installed above the plants	Suitable for almost all soil types Reduces soil compaction, increased yield	Necessity to build structure to carry the piping High initial investment
	Manual watering	Use of regular water hose with nozzle	Minimal equipment cost	Manual operation with no automation at all
Lightening system	Grow light grid	Installation of grow lights above the plants	No need for overly complicated control system	No dedicated control over the small zones

On the bottom of planter (Figure 2) a heating cable is installed so that it does not disturb the water drainage. Excessive moisture simply flows out from the planter along inclined floor. Soil watering is done by nozzles placed on the front and back walls of the planter. Both ends of watering tubes can be joined to general watering system by threaded components. Plants lightening is made by lamp places in the planter top. Required light intensity can be ensured by different lamp types. Planter rigidity is simulated (Tanjuhhin [14]), and analysed by mathematical methods (Gornostajev *et al.,* [15]).

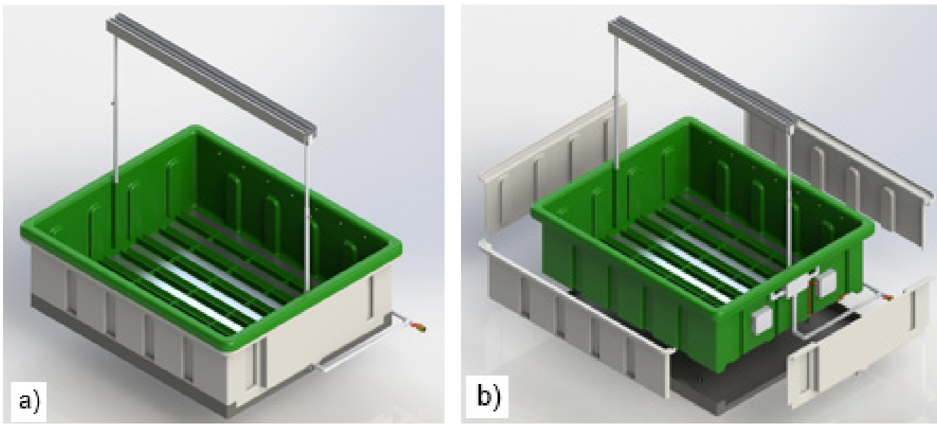

Figure 2. Planter with special equipment

Planter local electrical and watering systems can be simplicity joined to local systems of other planters and to greenhouse system as a whole.

2.2 Conditions and measuring

Separate planters usually are used for growing of defined types of plants. It is not limited plants nomenclature and required growing conditions for some types of plants are presented in Table 2. The system can be expanded with addition of new plants.

Generally, all parameters shown in the Table 2 should be controlled by monitoring system but some of them will be obtained by planter controller and some by greenhouse controller. Air temperature and moisture covers larger space than area of one separate planter and should be monitored by greenhouse measuring system. Soil electro-conductivity and acidity do not change abruptly and intensely and can be measured twice in the season by portative devices. Main parameters, light intensity, soil moisture and temperature are measured by sensors installed into planter. Measuring frequency can be some seconds and even milliseconds but for plants growing process it is not necessary to measure these parameters more often than once an hour or once a half of hour.

2.3 Communication

Base principle for communication and monitoring is shown in the Figure 3. Main component of communication system is a global cloud server where a constantly updated database is held, which contains parameters of growing conditions and recommendations. Greenhouses and planters have IP addresses and can be separated in the global system.

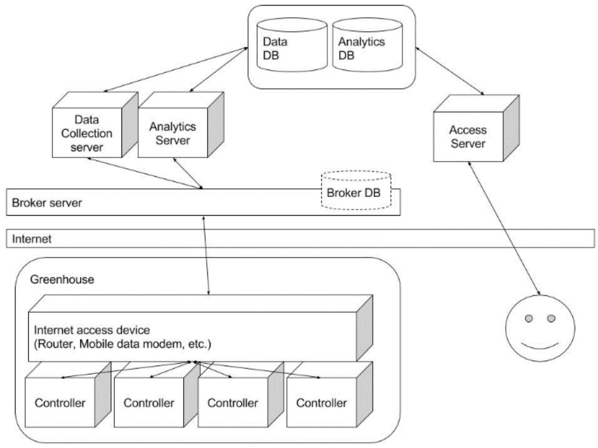

Figure 3. Principal scheme of the monitoring system

Table 2. Conditions for plants growing

Plant	Soil temperature, °C	Soil moisture, %	pH	Electro-conductivity, mS cm^{-1}	Air temperature, °C	Air moisture, %	Light intensity, x 1000 s
Cucumber	21 - 24	70 - 80	6.0 - 7.5	2.0 - 4.0	22 - 28	80 - 90	30 - 70
Tomato	16 - 26	60 - 70	5.5 - 7.5	2.0 - 5.0	20 - 25	60 - 75	30 - 70
Salad Leaf	18 - 21	50 - 80	6.0 - 7.0	1.5 - 2.5	15 - 26	80 - 90	30 - 70
Watermelon	22 - 30	75 - 85	5.5 - 7.0	1.0 - 2.0	25 - 35	60 - 75	30 - 70
Melon	26 - 30	75 - 85	6.0 - 6.5	2.0 - 2.5	18 - 25	60 - 75	30 - 70
Pumpkin	21 - 30	70 - 80	6.0 - 7.5	2.0 - 4.0	20 - 30	70 - 85	30 - 70
Paprika	23 - 29	60 - 70	5.5 - 7.0	2.0 - 2.5	22 - 28	70 - 90	30 - 70
Physalis	22 - 30	60 - 70	5.0 - 7.5	2.0 - 3.0	20 - 25	60 - 75	30 - 70
Eggplant	21 - 29	60 - 70	5.5 - 7.0	2.5 - 3.5	22 - 26	60 - 70	30 - 70
Maize	21 - 29	60 - 70	6.0 - 7.0	1.5 - 2.5	30 - 34	60 - 70	30 - 80
Basil	21 - 25	60 - 70	5.5 - 6.5	2.0 - 2.5	21 - 25	60 - 80	30 - 80
Tarragon	10 - 27	60 - 80	5.0 - 7.5	2.0 - 2.5	20 - 25	60 - 80	30 - 80
Spearmint	16 - 26	60 - 80	5.5 - 7.5	2.0 - 2.5	20 - 25	60 - 80	30 - 80
Rosemary	15 - 21	60 - 80	5.5 - 7.5	2.0 - 2.5	20 - 25	60 - 80	30 - 80

Planter controller periodically measures plant lightening, soil moisture and temperature by installed sensors. Greenhouse controller reads this information from all planters into the greenhouse and also measures air temperature and moisture by sensors. Server periodically reads this information from all greenhouses in the cluster, compares with required values and if it will be some deviations from norm sends a command to the greenhouse controller. The user (greenhouse owner) is able to receive the current state of all necessary parameters from the server by smartphone. In addition, he is able to change default values of growing conditions for its own greenhouse or separate planters.

3. Results and Discussion

Main result of this work is creation of a global monitoring system. Database is made according to growing conditions of fifteen types of plants and can be flexible expanded. System proposes to customer information about validated planter and conditions for its good growing. For online monitoring server periodically communicates with greenhouse microcontroller. Customer can get information by SMS or 4G connections.

Main problems can take place with measuring accuracy in one planter and correct communication into full system.

Soil temperature can be measured by sensors like LI-COR 7900-180 [16] but the problem is measuring depth. The temperature will be different on different soil levels. Soil heating have also some problems. It can be used a heating cable or mat but power should be selected according to soil type because thermal conductivity of different soil types is different [17].

The same problems can take place with soil watering. The current conditions can be measured for example by help of existing soil moisture sensors but measuring depth and time should be correct chosen. After soil watering the upper layer is very wet but moisture measuring in this moment will give not correct results.

Lightening system should registered solar light from morning to evening. Really it also is complicated enough because needs defining beginning and finishing of measurements time. It means if during daytime light intensity will not be enough extra light will be turned on in the nighttime. A bit better solution can be turning light on in the daytime if the light intensity will be less than defined level but in this case control system should be able to measure light intensity in real time. Excessive lightening problems can also take pace. It means if solar light will be too much it will be necessary curtains to use.

Common conditions into greenhouse will be measured by general sensors. If the temperature exceeds the required values, the windows will be opened. The same actions will be carried out if the air moisture will exceeds the required values. The system should be able to compare temperature and moisture into the greenhouse and outside of it.

One very important part of monitoring system is communication between planters and greenhouse and between greenhouses and server. Greenhouse microcontroller periodically reads information from microcontrollers of all planters and keeps this information. Server reads information from all greenhouses and compares obtained results with required values. The communication intensity should be separately defined for different greenhouses and planters. Database continuously updated by information of existing and new plants.

4. Conclusions

- An intelligent system for greenhouses monitoring is proposed. The system is able to separate single planters into greenhouse and keep necessary growing conditions in planter and into greenhouse as a whole.

- Current state of all necessary parameters can be delivered to the customer via common server. The server periodically compares information obtained from single greenhouses with required values.

- It also keeps information about plants growing conditions and continuously updates it.

Acknowledgments

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5. References

[1] Sergeev I., Krasilnikova E., Mukhutdinova S. (2017). *Monitoring Food Security and Safety in the Eurasian Economic Union (EAEU)*. Journal of Hygienic Engineering and Design, 19, pp. 49-54.

[2] Stevanovski M., Ziberoski J., Stevanovska K. (2014). *Successful Managing as Factor for the Development of Agribusiness*. Journal of Hygienic Engineering and Design, 8, pp. 119-123.

[3] Stevanovski M., Stevanovska K. (2010). *Managements basics*. MIT Univerzitet, Skopje, Macedonia.

[4] Meyer R. (2003). *Potential for increasing food quality. Working report no. 87*. Office of Technology Assessment at the German Bundestag, Berlin, Germany.

[5] Brosnan T., Sun W. D. (2004). *Improving quality inspection of food products by computer vision: A review*. J. Food Eng., 61, (1), pp. 3-16.

[6] Blasco J., Cubera S., Gomez-Sanchis P. M., Molto E. (2009). *Development of a machine for the automatic sorting of pomegranate (Punica granatum) arils based on computer vision*. J. Food Eng., 90, pp. 27-34.

[7] Dara F., Devolli A. (2016). *Applying Artificial Neural Networks (ANN) Techniques to Automated Visual Apple Sorting*. Journal of Hygienic Engineering and Design, 17, pp 55-63.

[8] GGS. (2017). *Commercial Greenhouse Structures & Design Built to Last*.

<URL: http://ggs-greenhouse.com. Accessed 17 September 2017.

[9] Ecoslider.

<URL: https://ecoslider.com/en. Accessed 17 September 2017.

[10] [10] Özbek S. (1978). *Special Fruit*. Faculty of Agriculture Publications, Cukurova University, Adana, Turkey, No 1, 128, pp. 486.

[11] Karadeniz T. (2014). *Plant Physiology*. Faculty of Agriculture Lecture Notes, Ordu University, Turkey.

[12] Karadeniz, T. (2001). *Fruit and Leaf Characters in 'Foşa' Hazelnut Orchards Facing Different Directions*. Acta Hort., 556, pp. 359-363.

[13] Schwarz P. A., Fahey T. J., Dawson T. E. (1997). *Seasonal air and soil temperature effects on photosynthesis in red spruce (Picearubens) saplings*. Tree physiology, 17, pp. 187-194.

[14] Tanjuhhin A. (2017). *Development of the Planter for Greenhouse Monitoring System*. BSc. Thesis, Tallinn University of Technology, Estonia.

[15] Gornostajev D., Aryassov G., Penkov I. (2016). *Calculation Method for Optimization of Barge Hull*. International Review of Mechanical Engineering, 10, (2), pp. 115-124.

[16] [Spectrum Technologies. (2017). *Weather monitoring*. Accessed 17 September 2017.

http://www.specmeters.com/weather-monitoring, 2017.

[17] Agriculture. (2017). *Soil Science* (in Russian).

<URL: http://racechrono.ru/pochvovedenie, 2017. Accessed 17 September 2017.