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Vitaly Lysenko^{1*}, Ihor Bolbot¹, Oleksiy Martynenko²,
Taras Lendel¹, Kateryna Nakonechna¹

¹National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony, Kyiv, Ukraine

²Dalhousie University, Canada
B3H 4R2, 6299 South Str., Halifax, Canada

Software of a mobile robot for phytomonitoring

Abstract. Currently, the world is intensively expanding the areas of research and use of mobile robots – mechatronic systems based on the latest achievements in mechanics, microprocessor technology, control and measurement systems, computer science, and control theory. To successfully complete a wide range of tasks, robots must have both mobility and the ability to interpret, plan, and automatically perform the resulting task using an on-board computing system. Their special feature is the ability to achieve a given goal in an uncertain external environment, avoiding collisions with stationary obstacles and moving objects. Now the confident functioning of mobile robots can be ensured in relatively familiar and well-structured workspaces. Methods of controlling robots based on well-formulated models and algorithms are developed. When working in an unfamiliar or changing environment, the mobile robot must be able to adapt to changes in the environment, respond to unforeseen situations, and act based on previous experience. Thus, the robot needs a control system with elements of artificial intelligence. As a control object, the robot is a multi-channel nonlinear dynamic system. Despite the fact that a number of studies have been conducted in the field of mobile robot management to date, universal approaches to the synthesis of automatic robot control systems have not been sufficiently developed. The purpose of the study is to substantiate the software of a mobile robot for phytomonitoring. The methodology is an algorithm implemented by this programme, which provides for reading and storing information about the state of plants and the value of technological parameters of the environment in the greenhouse. The paper substantiates a flowchart of the mobile robot control algorithm for phytomonitoring in industrial greenhouses. Given the significant area of an industrial greenhouse and, accordingly, a significant number of plants in it, it is necessary to calculate the distance to which a mobile robot for phytomonitoring can transmit a digital signal. The authors prove that the total power of the channel is equal to the sum of all the powers of the transmitter, receiver, and antenna of the transmitter, the sensitivity of the system, and the loss difference of the transmission system

Keywords: mobile robot, phytomonitoring, control system, closed greenhouse, control algorithm

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INTRODUCTION

Information about the parameters of the atmosphere and the state of plants (phytostate) in industrial greenhouses is essential and necessary to ensure guaranteed yield [1-3]. Growing plant products in industrial greenhouse plants is accompanied by quite large energy costs (up to 70% of the cost of production).

In addition, the output of products should be provided in the maximum quantity with the appropriate quality. The main factors that affect the profit of a modern indoor

enterprise that specialises in growing plant products are considered in [4].

Reduce energy costs for the production of technologically justified volumes of products and ensure their appropriate quality by developing the necessary strategies for managing the production of plant products using the results of monitoring the phytostate and atmospheric parameters by an intelligent mobile robot, which would allow getting the maximum profit of production.

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*Corresponding author

Analysis of Recent Studies in Ukraine, the production of the range of equipment used to assess the parameters of the atmosphere and plant conditions (phytostate) in closed greenhouses is extremely insufficient. The use of phytomonitoring [5; 6] as the main method of monitoring the technological parameters of plant development in greenhouses is considered in the studies by Guido Fagliaa, Camilla Baratto, Matteo Pardo, Massimo Maffeic, Marco Vezzolia, Luca Boarinob, Giorgio Sberveglia, Simone Bossic [7]. The basis of such developments are sensors for monitoring plant development, and their main disadvantage is their “binding” to one plant [8-10]. The paper by Chr. Lamnatou, D. Chemisana [11] primarily analyses the effect of solar radiation on the plant. Technical means accompanying the maintenance of microclimate parameters in a closed-ground structure were not described.

The purpose of the study is to create software for controlling the mobile phytomonitoring robot, which significantly complements the existing automation systems for vegetable production in industrial greenhouses.

RESULTS AND DISCUSSION

Based on the study results, the structure of the plant production management system in an industrial greenhouse is proposed, which, in addition to conventional components, includes a mobile robot for phytomonitoring, which, moving around the greenhouse area with technological guides, monitors the parameters of the atmosphere and plant phytostate with reference to the location, transmits the information obtained to the existing system for the formation of strategies for managing the production of plant products (Fig. 1).

The structure of the mobile robot for phytomonitoring is shown in (Fig. 1) and it is as follows: the control unit 1 determines the location for measuring phytometric parameters and sends control commands through the digital-to-analogue converter 2 to the actuators 3 of the mobile platform, to move the mobile platform 4 of the device to a given location along the guides that serve to move between the rows of plantings and are both greenhouse heating pipes and a platform for moving the ladder trolley. After reaching the specified location, the device stops and the control unit controls the actuators of the tower, which drive the horizontal sliding mechanisms 5 and ensure the rotation of the tower 6, the operation of the surveillance camera 7 and the movements of the vertical sliding mechanisms 8, equipped with a group of phytoclimatic and phytometric sensors 9 for conducting phytoclimatic, phytometric measurements and plant examination for diseases and pests. The measured values are sent via an analogue-to-digital converter 10 to the control unit, which then sends them to the data transmission unit 11 [12]. After the measurement, the process is repeated in reverse order and the mobile phytomonitoring robot moves to the next measurement point. After making measurements at all the necessary points, the mobile robot for phytomonitoring returns to the starting point or to the charging point of the power supply 12 of the entire device.

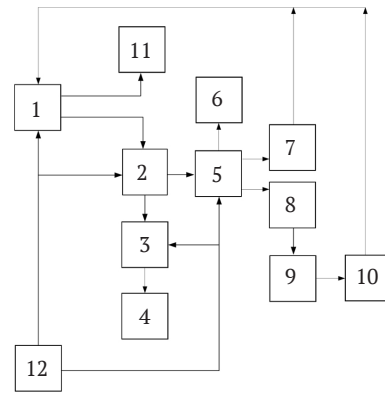


Figure 1. Diagram of links of mobile robot components

A mobile robot for phytomonitoring allows assessing the condition of plants over the entire area of an industrial greenhouse, processing information, and transferring it to the existing system to form a control action to ensure an appropriate microclimate. All this is implemented for the corresponding technological series, since phytometric parameters are measured in an ordinary way, which means that the assessment of plant development is carried out in an ordinary way. The mobile robot for phytomonitoring is equipped with a complex of phytometric sensors for measuring the phytometric parameters of a plant, which are sent through the data transmission unit to the data analysis unit of an industrial computer. A general algorithm for controlling a mobile robot for phytomonitoring in greenhouses was developed (Fig. 2), and for the hardware component of a mobile robot for phytomonitoring, a number of software products were developed that ensure its functioning [13; 14].

All software products run in the software environment of the Raspberry operating system – an analogue of Linux. The operating system was used to create software links between individual software products, which, in turn, manage the hardware components of the mobile robot for phytomonitoring. This operating system is widely used in software and computer engineering. In this case, its functionality allows creating an environment for managing the components of a mobile robot for phytomonitoring.

The Node-RED software environment is used to programme individual components of the mobile robot system for phytomonitoring (Arduino Mega controller), which has an open license, and its interface is shown in Figure 3. This software environment allows developing not only complex production software products in the form of flowcharts, which speeds up their development time for communication with Arduino devices, but also for developing a WEB interface for the purpose of working correctly with them.

The difficulty of developing the proposed software was the use of several programming languages. One of them is JavaScript (the main one for working in Node-Red). The NPM package management system was used for this purpose. This software product is installed on the basis of the Node-Red software environment to extend the functionality of the mobile robot for phytomonitoring. A flowchart for content management is shown in Figure 4.

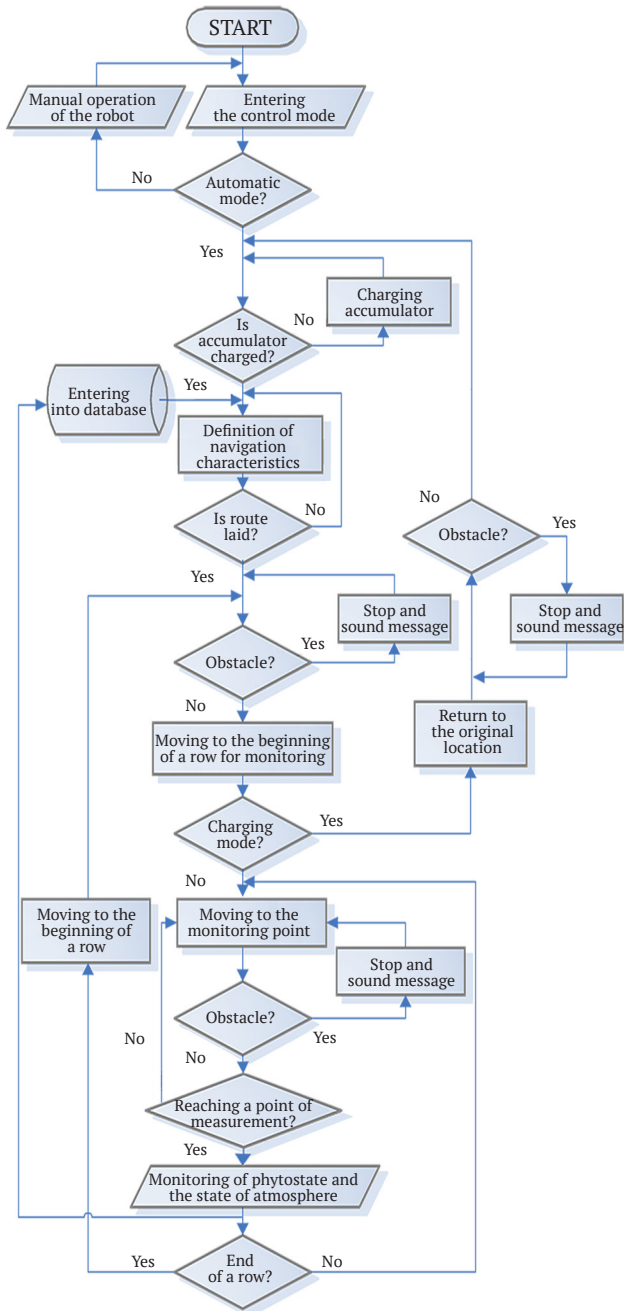


Figure 2. Flowchart of the mobile robot control algorithm for phytomonitoring in industrial greenhouses

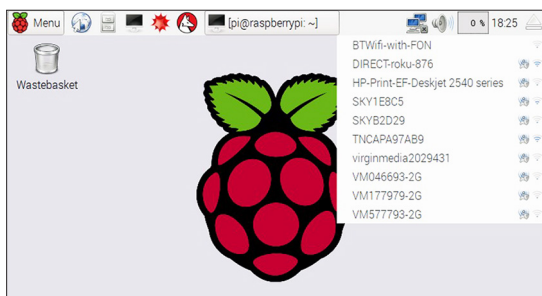


Figure 3. Programming interface for individual components of the mobile robot system for phytomonitoring of the Node-RED software environment

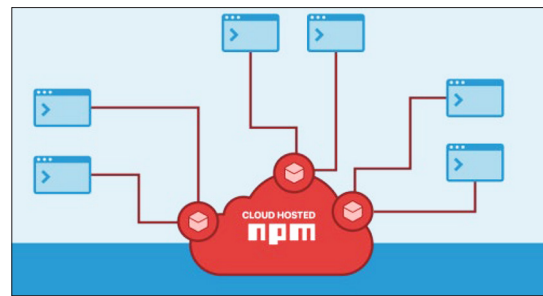


Figure 4. Content management flowchart

Notably, the blocks shown in Figure 3 are already ready-made programme code in JavaScript, where adjustments are made to ensure the performance of the programme as a whole.

In the developed software, the Arduino Mega connects to the Raspberry controller via a USB port and technically provides data transfer. For the correct operation of the entire system, the Arduino controller was initially programmed separately, and appropriate adjustments were made to its programme code. This action was performed to connect the Arduino Mega controller to the Raspberry controller using a specific protocol, the program code is made in the C++ programming language. At the final stage, the output of information was performed by splitting the data flow, after which it is displayed on a specially designed WEB interface and saved to a file for further use in calculations. The WEB interface of the mobile robot control system for phytomonitoring in an industrial greenhouse is shown in Figure 5.

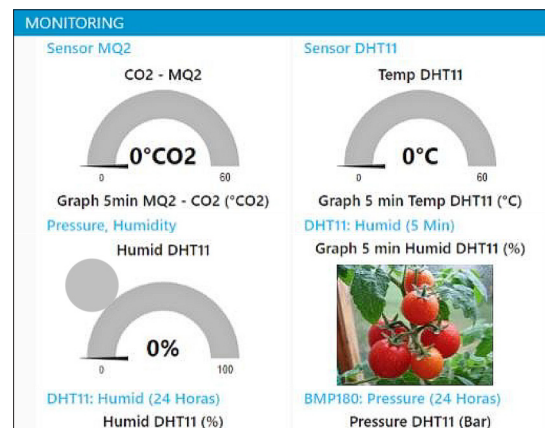


Figure 5. Interface of the mobile robot control system for phytomonitoring

This system also provides for the output of phytometric data. This information is obtained in a contactless way as an image of plants by a camera installed on a mobile robot for phytomonitoring. Analysis and processing of the corresponding phytometric data takes place by using wavelet transformations, when each photo image is decomposed into wavelet wave functions [2; 15].

To manage and gain access to the mobile robot for phytomonitoring, a graphical interface of the operator has been developed as part of: interface of the robot control

system (Fig. 6); interface of phytometric and phytoclimatic parameters of plants (Fig. 7); robot settings interface (Fig. 8).

Wi-Fi technology is used to transmit the received data by a mobile robot for phytomonitoring, since this technology

provides a high data transfer rate, and has a fairly long range, transmitting a large amount of data within a short period of time, and a high level of security [16-19]. The use of this technology is possible for most modern software environments.

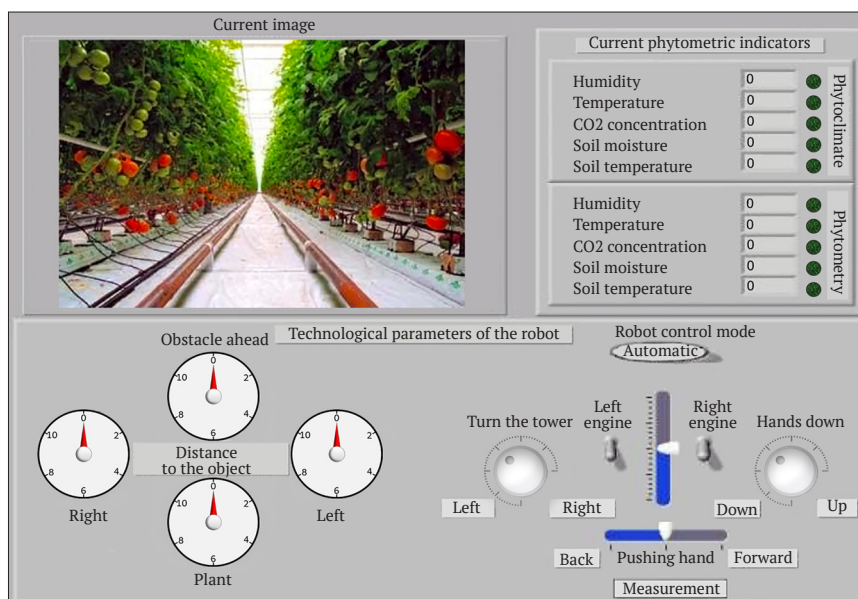


Figure 6. Interface of the mobile robot control system for phytomonitoring

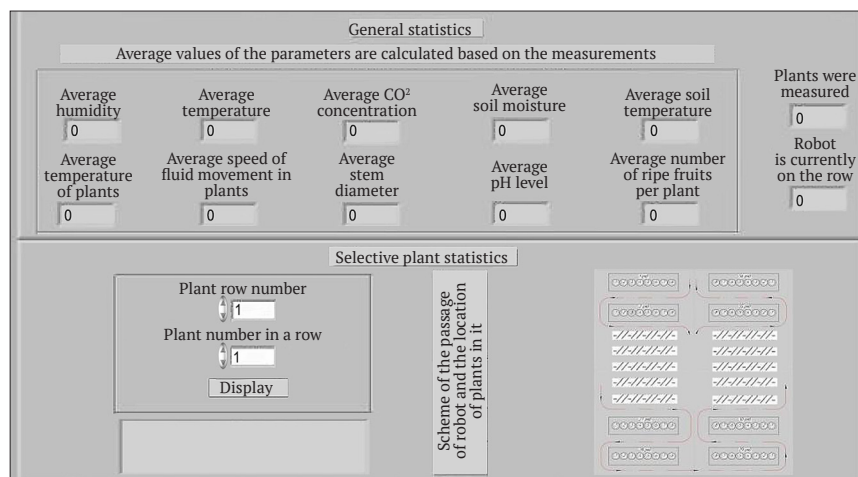


Figure 7. Interface of phytometric and phytoclimatic parameters of plants

The wireless local area network standard is used to transmit the received data from the mobile phytomonitoring robot to the control system. Considering the significant area of an industrial greenhouse and, accordingly, a significant number of plants in it, it is necessary to calculate the distance to which a mobile robot for phytomonitoring can transmit a digital signal:

$$D = 10^{\left(\frac{FSL}{20} - \frac{33}{20} \log F\right)} \quad (1)$$

where: F – transmission channel frequency, MHz; FSL (Free Space Loss) – losses in the digital signal space, dB.

Losses in the digital signal space are defined as

$$FSL = Y - S \quad (2)$$

where: S – channel gain margin, dB; Y – total channel power, dB.

To perform the necessary calculations, it is assumed that the channel gain margin is 20 dB.

The total power of the channel is equal to the sum of all the powers of the transmitter, receiver, and antenna of the transmitter, the sensitivity of the system and the loss difference of the transmission system used

$$Y = Pt - Pmin + Gt + Gr - Lt - Lr \quad (3)$$

where: Pt – transmitter power, dB; Gr – receiving antenna gain, dB; Gt – transmission antenna gain, dB; $Pmin$ – receiver sensitivity at the specified transmission rate, dB; Lr – signal losses in the coaxial cable and reception clock connectors, dB; Lt – signal losses in the connectors of the transmission path and coaxial cable, dB.

To calculate the wireless network, input data was used: the router’s operating frequency is 2,474 MHz, the transmission rate is 6 Mbit/s, its sensitivity is 88 dB. Hence, the total power of the transmission channel is determined:

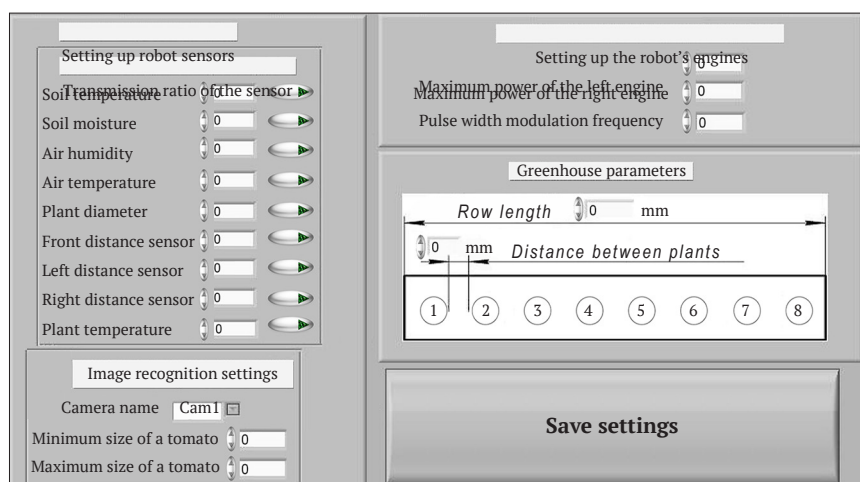


Figure 8. Robot settings interface

$$Y=18+88+5+5-3-3=110 \text{ (dB)}.$$

Accordingly, the losses in space will amount to:

$$FSL=110-20=90 \text{ (dB)}.$$

Then the distance to which information can be transmitted will be equal to:

$$D = 10^{\left(\frac{90}{20} - \frac{33}{20} - \lg 2472\right)} = 0.282 \text{ (km)}.$$

The calculated digital signal transmission distance for the developed mobile robot for phytomonitoring ensures reliable information acquisition, considering the design dimensions of an industrial greenhouse.

The mobile robot for phytomonitoring in an industrial greenhouse is used in conjunction with an intelligent control system for energy flows of the greenhouse, which allows the existing control system to form appropriate control strategies for electrical complexes to consider the spatial distribution of phytometric parameters, and to qualitatively control and perform a number of additional functions necessary for production: to control the parameters of the microclimate and conduct plant phytomonitoring, collect and process the received information of technological parameters in an industrial greenhouse;

to create data archives for further use; to function in automatic, manual, and remote control modes of the mobile robot.

CONCLUSIONS

1. The structure of the plant production management system in an industrial greenhouse has been developed, which, in addition to traditional components, includes a mobile robot for phytomonitoring.

2. A general control algorithm and software for using a mobile robot for phytomonitoring in industrial greenhouses based on the use of Node-RED and Processing/Wiring software environments have been developed.

3. It is recommended for hardware and software interactions of heterogeneous technical tools that are components of a mobile robot for phytomonitoring, using a flexible ROS platform; this creates conditions for ensuring the client-server architecture of a mobile robot and evenly distributing computing power.

4. The maximum distance of reliable digital signal transmission for a measuring complex in an industrial greenhouse is calculated – up to 282 metres.

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Віталій Пилипович Лисенко¹, Ігор Михайлович Болбот¹, Олексій Іванович Мартиненко², Тарас Іванович Лендел¹, Катерина Віталіївна Наконечна¹

¹Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

²Університет Далхоусі, Канада
В3Н 4R2, вул. 6299 South Str., Галіфакс, Канада

Програмне забезпечення мобільного робота для фітомоніторингу

Анотація. Нині у світі інтенсивно розширюються галузі досліджень та використання мобільних роботів – мехатронних систем, що базуються на останніх досягненнях механіки, мікропроцесорної техніки, контрольно-вимірювальних систем, інформатики та теорії управління. Для успішного виконання великого кола завдань роботи повинні мати як мобільність, так і здатність інтерпретувати, планувати і автоматично виконувати отримане завдання, використовуючи бортову обчислювальну систему. Їх особливість – можливість досягнення заданої мети в невизначеному зовнішньому середовищі, уникаючи зіткнень зі стаціонарними перешкодами та рухомими об'єктами. Зараз впевнене функціонування мобільних роботів може бути забезпечене щодо знайомих і добре структурованих робочих просторах. Розвинуто методи управління роботами на основі добре сформульованих моделей та алгоритмів. При роботі в незнайомому або змінному оточенні мобільний робот повинен мати здатність адаптуватися до змін у навколишньому середовищі, реагувати на непередбачені ситуації та діяти на підставі попереднього досвіду. Таким чином, робот потребує системи управління з елементами штучного інтелекту. Як об'єкт керування робот є багатоканальною нелінійною динамічною системою. Незважаючи на те, що до теперішнього часу проведено цілу низку досліджень у галузі управління мобільними роботами, універсальні підходи до синтезу систем автоматичного управління роботами розроблені недостатньо. Мета дослідження полягає в обґрунтуванні програмного забезпечення мобільного робота для фітомоніторингу. Методологія є алгоритмом, що реалізується зазначеною програмою, передбачає зчитування та зберігання інформації про стани рослин та значення технологічних параметрів навколишнього середовища в теплиці. В статті обґрунтовано блок-схему алгоритму керування мобільним роботом для фітомоніторингу у промислових теплицях. Враховуючи, значну площу промислової теплиці і відповідно значну кількість рослин у ній, потрібно розрахувати відстань, на яку мобільний робот для фітомоніторингу може передати цифровий сигнал. Авторами доведено, що сумарна потужність каналу дорівнює сумі всіх потужностей передавача, приймача і антени передавача, чутливості системи та різниці втрат системи передачі

Ключові слова: мобільний робот, фітомоніторинг, система керування, споруда закритого ґрунту, алгоритм керування