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ПРИЛОЖЕНИЕ ДЛЯ СМАРТФОНА ПО ОБНАРУЖЕНИЮ ГРИБНЫХ БОЛЕЗНЕЙ ЛИСТЬЕВ РАСТЕНИЙ

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Описаны симптомы и биофизические процессы, протекающие в землянике садовой при поражении ее доминирующим видом болезни (до 80%), вызванной грибами-возбудителями. Показана неэффективность визуальной оценки степени поражения болезнями земляники по условной 5-балльной шкале или в процентном отношении по площади, пораженной грибами листовой пластины, с привлечением квалифицированных специалистов. Для создания средств диагностики, позволяющих заранее обнаружить грибные болезни земляники садовой, предложен один из методов компьютерного зрения путем подсчета пикселей изображения в пространстве цветовых каналов красного, зеленого и синего цвета (R, G, B). Данный метод дает возможность определять степень поражения грибными болезнями отдельного листа растения. Алгоритм включает захват изображения с помощью цифровой камеры путем фокусировки на листе растения, размещенном на подложке с равномерным фоном, обеспечивающим контрастное выделение объекта; преобразование цветного изображения в черно-белое; разделение изображения между областями с некротическими пятнами и здоровыми областями листа растения с помощью маскирования и удаления пикселей; подсчет количества пикселей в этих двух областях и расчет их соотношения. Приведены сведения о компьютерной программе определения степени поражения листа земляники садовой грибными болезнями. В качестве языка для разработки логической части информационной системы использован язык программирования Java (операционная система Android Studio 3.4.1). Для построения графического интерфейса использовано обеспечение, облегчающее разработку и объединение разных модулей программного проекта LibGDX. Предлагаемый алгоритм реализован для персонального компьютера и может в виде программного приложения устанавливаться на смартфон, с помощью которого любой сельхозпроизводитель может осуществлять раннюю диагностику грибных болезней растений.

Ключевые слова: земляника садовая, диагностика, болезни, степень поражения, компьютерное зрение, смартфон

APP FOR SMARTPHONE FOR DETECTING FUNGUS DISEASES OF PLANT LEAVES

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The symptoms and biophysical processes occurring in garden strawberry plants when they are affected by the dominant type of disease (up to 80%) caused by pathogenic fungi have been described. The ineffectiveness of the visual assessment of the degree of damage to strawberry diseases by a conventional 5-point scale or as a percentage of the leaf plate area affected by fungi, with the involvement of qualified specialists, has been shown. To create diagnostic tools that allow early detection of fungal diseases of garden strawberries, one of the methods of computer vision was proposed by counting image pixels in the space of color channels of red, green and blue (R, G, B), which makes it possible to determine the degree of fungal diseases affecting an individual plant leaf. The algorithm includes capturing an image with a digital camera by focusing on a plant leaf placed on a substrate with a uniform background providing a contrasting selection of the object; converting a color image to black and white; dividing the image between areas with necrotic spots and healthy areas of the plant leaf by masking and removing pixels; counting the number of pixels in these two areas and calculating their ratio. Information about a computer software for determining the degree of damage to a strawberry leaf by garden fungal diseases has been given. Java programming language (operating system Android Studio 3.4.1) was used as a language for the development of the logical part of the information system. In order to build a graphical interface, the software facilitating the development and integration of various modules of the LibGDX software project was used. The proposed algorithm is implemented for a personal computer and can be installed on a smartphone in the form of a software application, with the help of which any agricultural producer can carry out early diagnosis of fungal plant diseases.

Keywords: garden strawberry, diagnosis, diseases, degree of damage, computer vision, smartphone.

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Conflict of interest
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INTRODUCTION

Products from plant materials not only provide the body with nutrients, but also contain a whole range of useful minerals, vitamins, and also increase the body's resistance to various diseases, i.e. are functional products [1]. Garden strawberry nutritious has an abundant biochemical composition and has high taste, valuable medicinal properties and an attractive appearance.

However, garden strawberries are affected by over 30 fungal, viral and bacterial diseases. Most diseases (about 80%) are caused by fungi [2]. Plant diseases are considered occupational hazards because they are difficult to detect and identify in advance. It is important for growers to detect diseases at an early stage in order to control their spread.

The earliest responses of plant cells to the action of pathogens and the elicitors produced by them (elicitors are exometabolites of the pathogen that bind to the host receptor and trigger a protective reaction) are an increase in the content of calcium ions and protons in the cytosol, a change in the parameters of the transport system of the plasma membrane, including rectifying selective potassium channels, electrogenic hydrogen ATPase pump, calcium-permeable and non-selective cation channels, and depolarization of the plasmalemma and tonoplast [3]. In addition, elicitors “turn on” various signaling systems of plant cells, which leads to the expression of protective genes, the synthesis of the corresponding proteins (antigens), the formation of phytoalexins - secondary metabolites that are never present in a healthy plant, the bulk of which are localized around the site of injury [3] . Phytoalexins lead to a slowdown in the synthesis of enzymes of the fungal phytopathogen, a slowdown in its growth, and sometimes its destruction. The synthesis of phytoalexins is taken over by healthy cells surrounding the necrosis. It is in them that these substances are formed, and then are directed towards danger - into the necrotic cells in which the parasite is located. It is also known that when the causative agents of fungal diseases are damaged, the hosts do not die quickly, but the intensity of photosynthesis of diseased plants is usually much lower than the norm [4]. This is mainly due to a violation of the structure of the photosynthetic apparatus of cells: the number of chloroplasts per unit leaf area, the volume of chloroplasts, the concentration of chlorophyll and the ratio of chlorophylls a and b decrease sharply.

The size of a single leaf of a plant and its area are important parameters on which the efficiency of converting the energy of visible light (photosynthesis) and maintaining the water balance of the whole plant depends [1].

The reaction of plants to the action of causative agents of fungal diseases is also the formation of specific colored necrotic spots on the surface of plant leaves and the configuration of their distribution [5]. Spots arise from disruption of chloroplast activity and a decrease in the content of chlorophyll in the leaves.

When developing a diagnostic tool for a fungal disease of a plant, it is important to determine the degree of damage to a particular leaf of a selected sample of garden strawberry by this disease. In practice, qualified specialists determine the degree of damage by the organoleptic method (according to a conditional 5-point scale or as a percentage of the area affected by fungi of the leaf plate) [6]. Consultation with experts to identify plant diseases is costly and time consuming. Determination of the degree of injury by production workers during the growing season of garden strawberry is subjective, individual and ambiguous, since it is carried out by mentally comparing the colored images of necrotic spots with templates from atlases [7].

Most methods for diagnosing diseases of cultivated plants require the use of expensive bulky equipment. They are invasive and long lasting [1].

The purpose of the research is to substantiate the effectiveness of the application of the express method of computer vision to determine the degree of damage to plant leaves and to create on its basis a portable device for monitoring the phytosanitary state of crops of cultivated plants in their production.

MATERIALS AND METHODS

Portable electronic technology is an essential companion to the life of modern people. This is due to the multifunctionality of such devices. For example, all manufactured smartphones are endowed with the functions of a telephone, a pocket personal computer, a music player and a camera. A smartphone is able to replace a light source, a control panel for various electrical engineering, a building level, a GPS navigator, etc. The evolution of portable electronic equipment is at a high pace and is developing by creating special software applications for the needs of people in various fields of their activity.

A promising direction is the use of smartphones as measuring and diagnostic tools. Currently, smartphones are being developed and are already being used as a "diagnostic center" for individual health by transforming it into a tonometer, thermometer, glucometer, electrocardiograph and other medical devices and devices. For example, thanks to the development of innovative digital technologies and artificial intelligence, smartphones have found wide application in the traditional diagnosis of human diseases [8]. The device in real time, through the application installed on the smartphone of the person caring for the patient, transmits data about his health: heart rate and breathing parameters, stress level and sleep cycles, etc.

Computer vision methods by counting image pixels in the space of red, green, and blue color channels (R, G, B) are promising for the implementation of plant disease diagnostics in the form of an application to a smartphone [9–14]. A commonly used indicator of plant health is leaf color, which is related to their chlorophyll content.

The development of an algorithm for the program for determining the degree of damage to plant leaves by diseases in the form of applications for a smartphone is based on the following methodological aspects.

Acquiring an image is the first step for any vision system prior to performing an image analysis procedure. The smartphone's digital camera is used to capture images at the required resolution. To improve image quality, it is necessary to maintain an equal angle and illumination. When approaching a leaf, the camera focuses on the leaf, which is positioned on a substrate with a uniform white or black background to obtain a contrasting image of the affected leaf of the plant.

The purpose of image preprocessing is to ensure the following condition: the extraction of informative parameters does not affect the background, size and shape of the leaf, the intensity of the light source, and the characteristics of the camera for diagnosing plant diseases [15]. Image preprocessing is also used to highlight certain features and reveal details in an image. At the same time, various methods are used, such as image filtering, resizing, segmentation, morphological and other operations[1]. In addition, the captured images may contain some noise. Noise removal is performed prior to image analysis using high pass, low pass, median and linear filters, etc. The image can also be enhanced to distinguish between subject and background. Once captured, the image is converted to a spatial representation of a different color if required for further analysis. In some cases, masking and pixel removal is required to detect diseases on plant leaves. Masking is setting the pixel value in an image to some other background value, or to zero. At this stage, it is necessary to identify highly colored pixels. For example, when identifying a disease, green pixels represent a healthy area of a leaf. Therefore, it is preferable to remove green pixels and save pixels from the infected part of the study area. Masking is performed based on the specified threshold. The red, green, and blue component of a pixel is set to zero if the green component of the pixel intensity is less than a pre-calculated threshold. Masking significantly reduces processing time, since disease segmentation is obtained by setting the non-disease portion to zero and 1 for the diseased portion of the leaf.

Image segmentation is the division of an image into an object and an area or background. When identifying a disease, it is used to separate the image between areas with necrotic spots and healthy areas in the leaves [16]. In some cases, the infected part, after it has been removed, is segmented into several spots of the same size.

RESULTS AND DISCUSSION

The algorithm for the implementation of the proposed method of computer vision was initially implemented on a personal computer using previously obtained color images of leaves of garden strawberry (see Fig. 1).

This is due to the need to thoroughly work out the program algorithm, since the computer display has a higher resolution and a larger display area of the program window than a smartphone display. In addition, when analyzing a sufficient number of images using the created program, it will be possible to identify inaccuracies in its operations and to correct or modify the program according to the data obtained using the experimenter's experience. The Java programming language (Android Studio 3.4.1 operating system) was used as a language for the development of the logical part of the information system. To build the graphical interface, we used software that facilitates the development and integration of various modules of the LibGDX software project. The LibGDX project is a cross-platform game development and visualization framework based on the Java programming language with some components written in C and C ++ to improve the performance of certain code. Currently supports Win-

[1]Tichkule S.K., Gawali D.H. Plant diseases detection using image processing techniques // Online International Conference on Green Engineering and Technologies (IC-GET). 2016. DOI: 10.1109/get.2016.7916653.

dows, Linux, Mac OS X, Android, iOS and HTML5 as target platforms[2].

With the help of a camera, a color image of a plant leaf is formed. Next, the resulting image is copied to the Input folder. The selection of an image from the folder is carried out using the vertical sliders of the mouse click (see Fig. 2).

Then the image is converted to the basic format in pixels so that it fits completely on the screen of the LibGDX program.

Next, the process of converting a color image to black and white occurs. The image transformation is segmented by analyzing the black and white color intensity distribution on the histogram to match the requirements of the plant disease dataset. A histogram is a graph with brightness located on the x-axis with a maximum size of 256 pixels. The y-axis is a sequence of pixels from 1 to 200 with the corresponding brightness level.

Once the image is segmented, the extracted area is processed to remove pixel areas that are dominated by green, i. e. the places where the leaf is considered uniquely healthy.

After that, using the slider under the graph, select the pixels of the desired brightness from 0 to 255, where 0 is black, 255 is absolutely white. At this stage, the pixels of the plant leaf area without a background are selected (see Fig. 3).

Then the degree of damage to the plant is determined (see Fig. 4). This procedure is performed by analyzing each pixel by comparing its color signatures, for example, comparing red to green, blue to green.

For a more accurate assessment, two histograms-graphs were created with the x-axis from 1 to 500 pixels and with the y-axis to display the red / green and blue / green pixel ratios vertically on them, which are responsible for

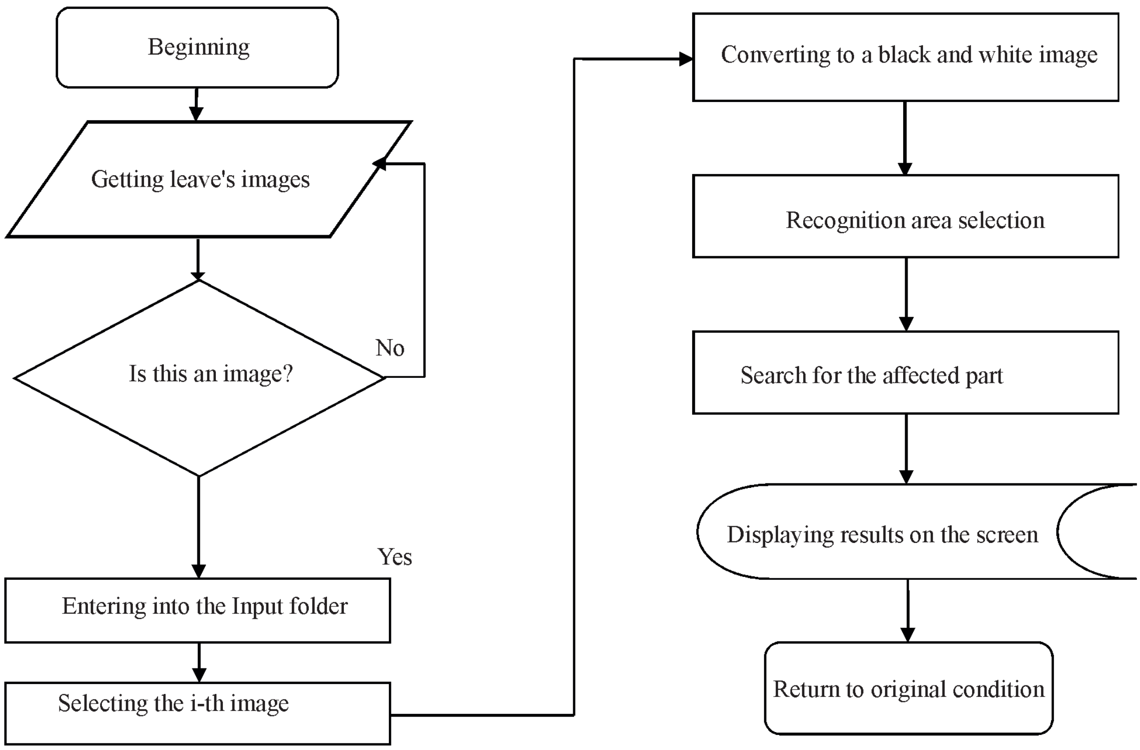

Рис. 1. Алгоритм программы определения степени поражения листа земляники садовой
Fig. 1. Algorithm of the program for determining the degree of damage to the leaf of garden strawberry

[2]libGDX – cross-platform framework for game development and visualization // On-line developer guide URL: http://www.libgdx.ru/p/guide.html (accessed date 10.02.2021).

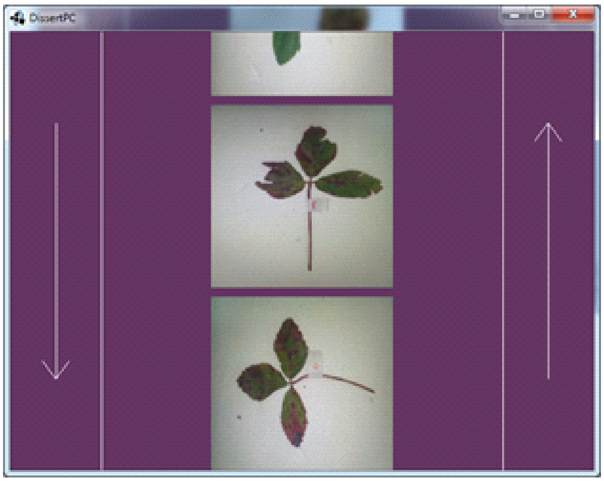

Рис. 2. Выбор изображения для распознавания
Fig. 2. Selecting an image for recognition

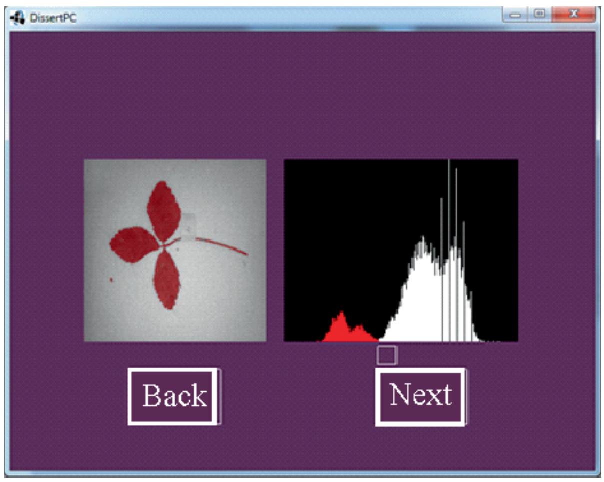

Рис. 3. Пример выбора распознаваемой области
Fig. 3. An example of recognized area selection

Рис. 4. Пример вывода результата обнаружения пораженной болезнями области растения
Fig. 4. An example of the result output of detecting a diseased plant area

removing the pixel areas in which red or blue predominated. (see fig. 4).

As the slider moves to the right along the x-axis, the number of pixels on the screen decreases in proportion to the peak in the histogram (in Fig. 4, the already filtered part is shown on the right).

Here is an example of calculating a peak on a histogram. Take a pixel with the following values: red = 70, green = 50, blue = 60. This pixel will be added to the element of the peak (red / green) array equal to (70/50) × 100 = 140, and the peak with coordinates on the x-axis equal to 140 will be higher by one.

Histograms of pixel array element values have peaks. The higher the peak on the histogram, the more pixels it has with this ratio. Thus, we reduce the number of pixels close to green and therefore find the affected areas. Then remove pixels where the green value is greater than the red and blue value. These questionable pixels with values in the array from 0 to 499 under the histogram are removed with the slider. After removing the questionable pixels, the affected part is calculated and displayed on the screen.

The introduction of the operations described above using two histograms and sliders will allow early diagnosis of diseases when its symptoms are still little noticeable to the observer.

The given algorithm and software are presented in the form of a basic block, which will be improved in the process of further research and experimental work.

When testing the basic block of the program in the field, it will be possible to take into account the observations and wishes of plant protection experts, agronomists, producers and other specialists in the cultivation of specific crops and its further adjustment and transformation. For example, due to the importance of such a plant trait as area, in the photosynthetic process and regulation of water balance, it becomes necessary to determine its size. In the future, it is necessary to solve other more complex problems, for example, the determination of the dominant fungal plant disease[3], the problem of classification of diseases [17].

CONCLUSION

Based on the variety of the computer vision method, which counts image pixels in the space of color channels of red, green and blue (R, G, B), an algorithm and software product has been developed for the automated determination of the degree of fungal diseases affecting the leaves of garden strawberry, which is more accurate than the widespread one organoleptic visual expert method.

The algorithm and software are presented in the form of a basic block, which can be supplemented and improved in the process of experimental work and to solve related problems to determine economically important plant traits.

The results of the study made it possible to create a software application that can be installed on the personal smartphone of any agricultural specialist. This application will be useful for detecting at an early stage of development of fungal diseases of various crops, as well as for monitoring the phytosanitary state of crops.

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