Automated diseases detection of plant diseases in space greenhouses

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Abstract. To detect plant diseases in a space greenhouse, a computer vision method is proposed by counting image pixels in the space of color channels of red, green and blue. An algorithm and a program have been developed for the automated determination of the degree of fungal diseases affecting garden strawberry leaves from the transmitted images of plant leaves. The research results can be used for early diagnosis of diseases and monitoring of the functional state of greenhouse plants.

1. Introduction
Long-term presence of man in space requires providing the crew with adequate nutrition with minimal replenishment from Earth. This is due to the reduced load on consumables for future space missions. Therefore, it becomes necessary to produce fresh, functional plant-based foods using greenhouses. In addition, the presence of greenhouses reduces emotional instability and mitigates the stress load on the crew [1]. For example, garden strawberry is nutritious, has an abundant biochemical composition and has a high taste. It has valuable medicinal properties and an attractive appearance. However, garden strawberries infect over 30 fungal, viral and bacterial diseases. Most diseases (about 80%) are caused by fungi [2]. Considering that the vegetation of plants in space conditions occurs at low gravity and illumination levels, the lack of necessary air convection, the problem of early detection of plant diseases is very urgent.

2. Problem definition
Diagnostics of diseases and their causative agents is an important link in the system of protection of plants growing in extreme conditions. Currently, a large number of special methods for detecting diseases with their inherent advantages and disadvantages are used in diagnostics. Diagnostic methods based on polymerase chain reaction, enzyme immunoassay and immune-chromatographic analysis are highly sensitive, but they are lengthy, laborious and invasive [2]. Visual diagnostics, which are widespread in practice, do not lose their relevance, as they are often preliminary for other diagnostic technologies. The main disadvantages of the visual method can be considered unreliability due to the coincidence of external signs of infectious plant lesions and physiological disorders caused by adverse external influences, the need for a highly qualified expert and the late detection of diseases.

The concept of using informative images of plant health monitoring is widespread, based on the development of a normalized difference vegetative index and the determination of the reflectivity of plant leaves in the near infrared range [3]. But this concept is not acceptable for localized health
assessments of plants grown in confined spaces. We propose to install color cameras of technical vision systems with high optical resolution to assess the health of plants in greenhouses. Then the images are transferred to the ground segment for its subsequent processing. For residential greenhouses, it is proposed to carry out early diagnosis of plant diseases using smartphones using computer vision methods, for example, based on counting image pixels in the space of color channels of red, green and blue (R, G, B).

3. Materials and methods
Portable electronic equipment is an indispensable companion in the life of a modern person. For example, all manufactured smartphones are endowed with the functions of a telephone, a pocket personal computer, a music player and a camera. The 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 through the creation of special software applications to meet the needs of the population in various areas of its 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 blood pressure monitor, thermometer, glucometer, electrocardiograph and other useful 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 [4].

The device in real time, through an 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.

To implement the diagnosis of plant diseases in the form of an application to a smartphone, computer vision methods are promising by counting image pixels in the space of color channels of red, green and blue (R, G, B) [5-10].

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 was based on the following methodological aspects.

Imaging is the first step for any vision system prior to performing image analysis. The smartphones 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 create a contrasting image of the affected plant leaf.

The purpose of image preprocessing is to guarantee 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 [11]. Image preprocessing is also used to highlight certain features and reveal details in an image. In this case, various methods are used, such as image filtering, resizing, segmentation, morphological and other operations [12]. 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, images are 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 zero. At this stage, the highly colored pixels need to be identified. For example, when identifying 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 because disease segmentation is obtained by setting the non-disease portion to zero and «1» to the diseased portion of the leaf.

Image segmentation is the division of an image into an object and an area or background.

In disease identification, image segmentation is used to separate the image between areas with necrotic spots and healthy areas in leaves [13].

In some cases, the infected part, after it has been removed, is segmented into several spots of the same size.

4. Experimental results

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

![Flowchart for the program algorithm](image)

**Figure 1.** Algorithm of the program for determining the degree of damage to the leaf of garden strawberry.

This is due to the need to thoroughly refine the program algorithm, since a computer display has a higher resolution and a larger program window display area 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 and the Android Studio 3.4.1 operating system were used as a language for the development of the logical part of the information system. To build the graphical interface, software was used to facilitate 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 Windows, Linux, Mac OS X, Android, iOS and HTML5 as target platforms [14].

With the help of a camera, a color image of a plant leaf is formed. Then the resulting image is copied to the "Imput" folder. The choice of an image from a folder is carried out using vertical sliders and a mouse click (figure 2).

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

![Image](image.jpg)

**Figure 2.** Selecting an image for recognition.

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 a 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 a corresponding brightness level.

Once the image has been segmented, the extracted area is processed to remove pixilated areas that are dominated by green, that is, places where the leaf is considered to be unambiguously healthy.

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

Then the degree of damage to the plant is determined (figure. 4). This procedure is performed by analyzing each pixel by comparing its color signatures, for example, comparing red to green and 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 removing the pixel areas in which dominated red or blue color. As the slider moves to the right along the $x$-axis, the number of pixels on the screen decreases in proportion to the peak on the histogram (figure. 4).
Figure 3. Selecting the sheet area.

Figure 4. Display of the result of the lesion assessment.
Here is an example of calculating a peak on a histogram. Take a pixel with values red = 70, green = 50, blue = 60. This pixel will be added to the element of the peak (red / green) array equal to \((70/50) \times 100 = 140\), and the peak with the \(x\)-axis coordinates 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 array values from 0 to 499 under the histogram are removed with a slider. After removing the questionable pixels, the affected part is calculated and displayed on the screen.

5. Results and discussion
The introduction of the aforementioned operations using two histograms and sliders will allow diagnosing diseases when its symptoms are still little noticeable to the observer. It should be noted that the above 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.

Of course, in the future, it is necessary to solve other more complex problems, for example, determining the dominant fungal plant disease, the problem of classifying diseases [15].

6. Conclusion
On the basis of one of the computer vision methods, which counts image pixels in the space of red, green and blue color channels (R, G, B), an algorithm and a program have been developed for the automated determination of the degree of damage to plant leaves by fungal diseases.

In this case, images from an uninhabited space greenhouse can be automatically transmitted to Earth with the required period of time.

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

The research results can be implemented in the form of a software application that can be autonomously installed on the researcher's Smartphone and will be used by him for monitoring the sanitary state of the space greenhouse.

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