Effect of recording device parameters on the operation of the sugar beet recognition algorithm in the early stages of growth

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Abstract. This experiment makes it possible to estimate the influence of the distance from the recording device lens to the ground on the recognition algorithm by comparing the area of the recognized part of the plant. The experiments are based on the fact that the main error of the algorithm is to reduce the area of the recognized part of the plant with a significant deterioration of parameters. The study carried out a number of experiments including a gradual change of height from the minimum structurally possible value to the maximum at which there is a significant loss of quality under different lighting conditions ensuring normal operation of the vision algorithm.

1. Introduction
Machine vision is a section of robotics that uses image analysis to solve industrial problems. This technology is widely used in production and in particular in agriculture. Machine vision technologies together with positioning systems are often fundamental in the development of devices for agricultural operations in precision farming. For example, by using unmanned aerial vehicles topographic maps of the terrain are created and the application of image processing technologies to them makes it possible to obtain 3D models of the Earth's surface with the ability to determine any geometric dimensions. The error of geometric measurements does not exceed tens of centimetres. Machine vision systems can also be used to count the number of berries and leaves of grapes. In case if the vine has few leaves, the quality of grapes will be low, if it too much – the berries will not get enough water, so it is extremely important for agricultural producers to know their exact quantity it determines when and how to water the plant [1, 2].

The most important features of the vision system are performance, ease of use, easy installation, complete solution (including software), price, reliability, technical support, versatility of settings, speed, complete set of diagnostics. Image processing and analysis are mainly focused on working with 2D images. These operations include contrast enhancement, edge detection, noise elimination or geometric transformations such as image rotation. These operations assume that image processing/analysis operates independently of the content of the images themselves [3].

This paper deals with the application of machine vision based on image recognition, an area that uses various methods to obtain information from video data, mainly based on a statistical approach. The process of weed vegetation works according to the following principle – identification of cultivated plants, anything that is not the last one to be removed. This approach is used in the selective
application of herbicides and mechanical removal of weeds while avoiding damage to cultivated plants [4].

2. Materials and methods

The experiment was conducted on a laboratory stand (figure 1) that consists of:

- the platform with guides;
- carriage;
- step engines;
- video camera;
- working body;
- system of mechanical and chemical removal of weed vegetation;
- container with herbicide;
- pump;
- control package;
- the electronic computer with specialized software [5].

![Figure 1](image1.png)

*Figure 1. The robotic weed control complex developed during the research work.*

It simulates the working conditions of an autonomous robotic complex for point control of weed vegetation. The movement of the platform with the guideways on which the carriage is mounted is installed by stepping motors within a limited volume. The carriage is equipped with a video camera and a working body which contains a system of simultaneous mechanical and chemical removal of weeds vegetation. The working device is connected through a pump to a container with herbicide. Outside the working area there is a control unit and an electronic computer with specialized software for image analysis [6].

Plant elements are characterized by values above the threshold $\zeta$, when subtracting $ExR$ from $ExG$.

Here, $ExR = (2r - g - b)$ excess of red, and $ExG = (2g - r - b)$ – excess of green. Where $r = R^*/(R^* + G^* + B^*)$, $g = G^*/(R^* + G^* + B^*)$ and $b = B^*/(R^* + G^* + B^*)$ are chromatic coordinates, and $R^*$, $G^*$, and $B^*$ are normalized values of RGB (0-1). The principle is illustrated in figure 2.

![Figure 2](image2.png)

*Figure 2. Plant identification using the ExG - ExR method.*
As a recording device various options were considered. There are 1D-, 2D-, 3D-cameras. 1D-cameras also called linear or line cameras are a kind of CV-cameras which differ from usual that images in them are formed by scanning the subject. 2D-cameras this is the cameras creating images in two-dimensional space in width and height. 3D cameras are used when it is necessary to analyze the volume of objects, their shape or their position in three-dimensional space. In this work were taken 2D cameras due to the wide availability and ease of use of the algorithm.

Cameras are also divided into analog and digital cameras. The former are for creating video surveillance network, as they are cheap, easy to install and use, resistant to hacking and have no delays in data transmission. If you use cameras of new standards with high resolution pictures such as HDCVI, HD-TVI or AHD, you can get good image quality including moving and remote objects. In a digital camera the signal is not converted back from digital to analog for transmission but is sent digitized form. Before transmission it can be encoded and compressed. This happens in IP cameras or transmitted uncompressed and unencrypted so in HD-SDI cameras. Optimal for this test bench is a digital camera [7].

CMOS was selected by matrix type. Among the advantages of this matrix stand out is high speed, low power consumption, cheaper and simpler production. The disadvantages are low light sensitivity, pixel filling factor and dynamic sensitivity as well as high noise level [8]. Table 1 below shows the remaining characteristics of the recording device selected for laboratory testing.

| Table 1. Characteristics of the Recorder. |
|------------------------------------------|
| Matrix type | CMOS |
| Matrix resolution | 3 MPix |
| Maximum frame rate | 30 frame per sec |
| Mainum permission. | 1920x1080 Pix |
| Used optics | Carl Zeiss Tessar |
| Lens material | Glass |
| Number of lenses | 1 |
| Digital zoom | 4x |
| Auto Focus | Yes |
| Auto. white balance adjustment | Yes |
| Low light photography | Yes |
| Indication of power on | Yes |
| Case material | Plastic |
| Horizontal rotation | 90° |
| PC Communication Interface | USB 2.0 |
| USB cable | Integrated |
| Cable Length | 1.8 m |
| Color | black/silver |
| Overall size | 94x43x71 mm |
| Video camera weight | 162 g |

This choice provides the fulfillment of all necessary requirements for the algorithm's work but it has a number of disadvantages. Testing the operation of the algorithm depends heavily on the quality of the recorder. There are specialized solutions for technical vision technology this is machine vision cameras. The latter shoot images in high resolution and send them uncompressed to your computer. Can have a resolution from VGA to 86 Megapixels for line scan or 4K for single-line scan and shoot
up to 200 frames per second. The machine vision camera produces images that are optimal for computer processing, analysis, measurement, diagnostics, recognition and control. In further wor, based on the results of the study is planned to move to this type of recording device but at the stage of testing the developed algorithm is sufficient and convenient solution is the camera specified in the table.

The figure below shows an image of the process of light measurement obtained by the robotic complex recording device while performing the recognition algorithm.

Figure 3. Measurement of illumination of stand of autonomous robotic complex for control of weed vegetation.

3. Results and discussion
To assess the performance of the algorithm at different values of illumination the agricultural crop - sugar beet was chosen.

Figure 4 shows the result of the previous work is a graph of the dependence of the area of the recognized surface on a natural light source which simulates the field conditions of the robotic complex.

Figure 4. Plot of independence of area of the recognized surface on a natural light source.
At an illumination value of 5000 to 6000 lux the recognition of sugar beet with maximum quality was achieved. This illumination range extends over most of the day. To ensure that the algorithm works in low light conditions it is possible to use artificial light sources similar to natural light in the average range of experiments. The possibility of selection up to spectral distribution in particular imitation of sunlight will allow to use the complex during the whole time of day.

In total this study will examine the effect of the distance from the lens to the soil in the optimal illumination range - from 5000 lux to 60000 lux in 5 experiments gradually increasing the value from minimum to maximum specified.

Below is a number of photographs with successive magnification from 20.5 cm to 40.5 cm. 20.5 cm is the minimum permissible design value of the unit and ensures optimal operation of the complex in the field [9].

**Figure 5.** Images of the vision algorithm recognition results from 20.5 cm to 40.5 cm in 2 cm increments for an illumination of 41000 lux.
Figure 5 shows the results of the first experience. The numerical values are shown in Table 2 and are shown in Figure 6.

**Table 2.** First experience results.

|  | h1 | h2 | h3 | h4 | h5 | h6 | h7 | h8 | h9 | h10 | h11 |
|---|----|----|----|----|----|----|----|----|----|-----|-----|
| h1 | 20.5 | 22.5 | 24.5 | 26.5 | 28.5 | 30.5 | 32.5 | 34.5 | 36.5 | 38.5 | 40.5 |
| S | 51597.0 | 42544.0 | 37015.0 | 29943.0 | 26234.0 | 22152.0 | 20464.0 | 14896.5 | 15472.5 | 14236.0 | 10890.5 |

**Figure 6.** Results of the first experience.

It is obvious from the photographs that the number of pixels characterizing the plant decreases as the height increases. In order to actually evaluate the effect of height on the quality of the algorithm it is necessary to process the results so as to exclude the reduction of the plant in the frame. For this purpose, we will use the formulas:

\[ S_1 = S'_1; \quad S_2 = S'_2 \frac{h_2}{h_1}; \quad S_3 = S'_3 \frac{h_3}{h_1}; \quad S_4 = S'_4 \frac{h_4}{h_1}; \ldots \]

After normalizing the values of all experiments, Table 3 was obtained.

**Table 3.** First experience results

|  | h1 | h2 | h3 | h4 | h5 | h6 | h7 | h8 | h9 | h10 | h11 |
|---|----|----|----|----|----|----|----|----|----|-----|-----|
| h1 | 20.5 | 22.5 | 24.5 | 26.5 | 28.5 | 30.5 | 32.5 | 34.5 | 36.5 | 38.5 | 40.5 |
| S | 51597.0 | 42544.0 | 37015.0 | 29943.0 | 26234.0 | 22152.0 | 20464.0 | 14896.5 | 15472.5 | 14236.0 | 10890.5 |

4. **Conclusions**

This experiment allows to estimate the influence of the distance from the recording from the lens to the soil on the recognition algorithm operation by comparing the area of the recognized part of the...
plant [10–12]. As you can see the main error of the algorithm is that at a significant deterioration in the parameters of the system partially does not recognize the plant. This fact was the basis for the experiment. Below in figure 7 there is a diagram of the results of five experiments after data processing in particular the normalization of parameters.

![Diagram](image)

**Figure 7.** Results of all experiments after normalization of indicators.

As you can see from the charts after 30.5 cm the algorithm failures begin and resulting in the data spread shown in figure 7.

In addition, the total decrease of the recognized plant area can be seen taking into account all experiments.

In total we can conclude that increasing the distance to the soil has a negative impact on the work of the algorithm, especially it manifests itself from 30 cm. At the same time optimal work is provided in a wide range from 20 cm to 30 cm.

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