Principles of functioning of the autonomous device for weed control for precision agriculture

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Abstract. The article shows the results of creation of a system aimed at reducing the negative impact on the ecological situation and biological systems while eliminating weeds in beetroot production. Methods of controlling weeds using machine vision technology are examined. For machine vision algorithms a library of images has been prepared. An algorithm and technical device have been developed for cultivating the soil on the early stages of beet growth.

1. Introduction

In recent decades, over-reliance on herbicides in beet production has caused serious environmental and biological problems in the areas adjacent to the land and in the areas where crops are grown, such as soil and groundwater contamination and the emergence of herbicide resistant weeds. A potential solution to reduce the use of herbicides while maintaining control over undesirable vegetation is the sharing usage of chemical and mechanical treatments. Accurate detection of weeds is a prerequisite for the implementation of this weed control strategy. In this study, a computer vision system has been developed to recognize weeds using contour and color identification techniques on the image. The system includes an algorithm of segmentation of the researched object with the help of OpenCV (Phyton) library for binaryization of images of weeds for the purpose of further processing and procedures of extraction of the object features. Subsequently, a classifier will be created on the basis of a support machine (SM) to identify different types of weeds using morphological features [1; 2].

The key requirement for the control of weeds is the precise detection of the position and the identification of weeds. The detection and removal processes must be synchronized with the movement of the carrier vehicle, which serves as a robotic weed control device for mobility. This requirement defines the minimum values of the system performance and accuracy.
2. Experimental details
The principle of operation of the device for control of weeds with regard to the process of recognition of weeds with the use of computer vision can be formalized in the form of a block diagram shown in Figure 1 of the process. [3]

![Figure 1. Block diagram of weed recognition process](image)

The installation is equipped with sensor systems that allow the autonomous identification of the required objects. After detection of weeds, mechanical treatment is carried out, followed by introduction of a small amount of herbicide into the root system of the weed. This approach reduces the cost of using the herbicide by reducing the amount of the herbicide during spot introduction and reduces the environmental impact, which has advantages over the general spraying of herbicides. An additional environmental effect can be achieved by using lightweight mobile chassis, instead of full-size tractors, due to less soil compaction due to the lower weight of agricultural machinery.

3. Experimental results
The detection of weeds is done with the help of technical vision, and this method will be described below in relation to the task of identifying the type of vegetation. The main drawback of this method is the dependence on the degree of illumination. The reason for the unstable illumination can be cloudiness, the change in the relative position of the Sun, the presence of shadows cast by the overall agricultural machinery, as due to these factors the amount of light falling on the cultivated soil decreases and as well as the quality of the image obtained. The most serious potential obstacle associated with changes in light level is the low degree of image processing, which can be minimized by the use of automatic shutter speed control or automatic adjustment of the aperture to ambient conditions [4]. In addition, changes in light levels and shading may result in inefficient or unsuitable traditional processing methods for image
segmentation to identify weeds [5]. The most common solution is the use of machine learning methods for segmentation of images and weeds [6]. Figure 2 shows soil samples for studies with different weed densities.

Figure 2. Soil samples for the study: a) sample with high density of weeds; b) sample with medium density of weeds

For the definition of type of a plant it is necessary to define preliminary borders of a plant and a background [7]. For this purpose, pixels that display plant areas are given high RGB values, while the background is given low RGB index values. Plant elements are characterized by values above the threshold $\zeta$, when subtracting $\text{ExR}$ from $\text{ExG}$.

Here, $\text{ExR} = (2r - g - b)$ excess of red, and $\text{ExG} = (2g - r - b)$ – 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) [8]. The principle is illustrated in Figure 3.

Figure 3. Plant identification using the ExG - ExR method: (a) original image; (b) extraction of vegetation by subtraction; (c) determination of plant contour (d) plant without gravel background

4. Discussions

First of all, it is necessary to ensure that the identification area is covered by the vision system. In order to ensure the coverage of the identification area, the following solutions can be used: the use of several mutually adjusted cameras; the use of a single camera located on a movable base. Below the variant of implementation of the method with a movable base is presented.

The design of the slider for photo and video shooting has a carriage with four rollers and a platform for mounting the camera. As guides steel profile with diameter of 20 mm and length of 1 m is used.
Control is carried out by four stepper motors. End sensors, microcontrollers and a computer. The platform can vary in size from 1 m$^2$ to 4.5 m$^2$. With additional hardware and modifications it is expected that scale up to about 50 m$^2$ will be produced in the future.

Figure 4 show the working unit developed on the basis of the Federal Scientific Agroengineering Center.

![Figure 4](image)

**Figure 4.** The autonomous robotic weed control complex developed during the research work: a) complete installation; b) working unit at the moment of vegetation processing

5. **Conclusions**

The method, algorithm and technical device for identification and destruction of weeds at early stages of beet growth are developed. A prototype of the carriage for camera positioning has been developed. The algorithm can be used for research and recognition with the use of machine vision technology of cultivated plants and weeds.

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