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RECOGNITION AND LOCATION OF CROP SEEDLINGS BASED ON IMAGE PROCESSING

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With the development of digital image technology, we can easily obtain a large number of crop growth images. Through effective analysis of the image, the growth information of crops can be obtained, which can better direct agricultural production. The efficiency of traditional seedling growth monitoring is low, especially in large-scale farmland, which takes a lot of time. Artificial method timely restricts scientific decision-making of cultivation crops. The progress of machine vision and image processing technology provides a new way for harmlessly monitoring of crop seedling growth .The results of image analysis can help agricultural producers to understand the growth of crop seedlings quickly and accurately, so as to take effective management as soon as possible. In this paper, the images of sunflower seedling collected in farmland environment are taken as the research object. The main research content is to segment green crops from soil background. Segmentation method of sunflower seedling image based on color features and Ostu threshold segmentation is proposed. The method is simple in calculation, and can adapt to the segmentation of farmland environment images, which lays the foundation for crop recognition process. Based on the image recognition results, the algorithm locates the seedlings. Through the rapid identification of sunflower seedlings, it is possible to fill the gaps with seedlings where the seedlings are less distributed. On the contrary, if the seedlings are too dense, the number of seedlings needs to be reduced. The algorithm provides a basis for precise management. The results show that the algorithm with extra green feature can quickly and effectively identify sunflower seedlings from background, and locate the seedlings based on the image recognition results. This algorithm is not sensitive to soil moisture and light conditions, and is less affected by crop residual coverage, so it can adapt to different soil environment which realize the non-destructive monitoring of sunflower seedlings.

Key words: *image segmentation; machine vision; color features; green identification; adaptive threshold method*
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Introduction. With the development of machine vision and digital image processing technology, agricultural information management has been realized, and the development of precision agriculture is a trend (Hamuda et al., 2016; Iqbal et al. , 2018; Nguyen et al. ,2019). Farmland managers can keep abreast of the crop growth and be provided scientific guidance for the management of farmland. Various remote devices such as satellites, airplanes, or Unmanned Aerial Vehicles (UANs) are used to monitor crops on the farmland through real-time analysis and processing of aerial images (Lei et al., 2017; Zhang et al., 2019; Pena et al. ,2015; Di Gennaro et al. ,2019). Many researchers use digital image processing techniques to detect the symptoms of diseases automatically as early as they appear on the growth stage of plants. They used different methodologies for the analysis and detection of plant leaf diseases (Khirade et al., 2015; Singh et al., 2015; Pujari et al. ,2015; Oo & Htun, 2018). With the development of precision agriculture, it requires to predict the crop yield with low cost. It can be solved by image processing technology which makes a correct judgment on the plant annual yield (Filippi et al., 2020; Tedesco et al., 2020). Recent advances in technology provide new tools to solve challenging computer vision tasks such as object detection, which can be used for detecting and counting plant seedlings in the field (Samiei et al., 2020; Jiang et al., 2019; Feduck et al., 2018; Quan et al.,2019). Plant seedling detection combines the theory of graphics processing and recognition in computer science with possibility of field automatic work or reseeding and thinning of crop seedlings.

Sunflower is one of the four major oil crops in the world, it is grown on 25.4 M • ha. The area under this crop in Ukraine is 5.1M • ha. The main sunflower producing areas of China are distributed in the Northeast, Northwest and North China regions, with high production potential, and can be expanded to the Southwest, Central South and East China regions (Zhang & Gu, 2018). With the development of science and technology, new technologies have played an important role in the production and growth of sunflower. Some researchers use image processing technology to recognize and locate sunflower seedlings, then provides the theoretical basis for the robot to automatically implement sunflower seedling reseeding and thinning operations (Yin et al. , 2010).

According to different application requirements, crop recognition based on image processing is researched (Gong, 2014; Chen et al. 2019; Tian et al., 2015). Sun Ming et al. proposed an automatic recognition technology by analyzing the color images of seedlings, which can identify each radish seedling in the image (Sun & Ling, 2002). Wang Sile et al. achieved the separation of green plants from complex background elements by constructing the decision tree based on HSV and color dispersion, and better adapted to changes in the brightness of the field image (Wang et al. 2015). Ke Qiuhong et al. proposed the method for extracting green plant areas from digital images, to solve the interference of soil background in the image and the influence of different lighting conditions on it, and achieve non-destructive measurement of plants (Ke et al. , 2013). Zhang Zhibin with colleagues adopted RGB color system and proposed the fast segmentation algorithm of ridge and row structure based on color features (Zhang et al., 2010). Wang Xue and Guo Xinxin proposed the green crop image segmentation method combined with Ostu method of the largest inter-class variance based on G-R color features, it can separate green crops from complex soil background not affected by uneven outdoor light (Wang & Guo, 2018). All these studies improved the recognition effect on crop images from various aspects, but have not studied the precise position of crops. The goal of our study is to quickly identify sunflower seedlings on digital images and provide position information for precision management of farmland.

Materials and methods.

1.1. Sowing method

Sunflower varieties are mainly divided into two types: edible and oil. Sowing methods differ for them. Sunflower of the oil type have 70 cm row space and 40 cm plant space. There are 30,000–37,500 seedlings per hectare for ordinary varieties. Digging holes are used for sowing, the depth of the holes is 3 cm–4 cm, and 1–2 seeds are placed on each acupuncture point. After emergence of plants, seedlings should be checked and supplemented timely. When the seedling reaches 2–3 pairs of leaves, it is necessary to carry out thinning in time.

1.2. Analysis of crop color characteristics

The object color is determined by the reflected light characteristics, and the color of an opaque object depends on the light color it reflects. The characteristic of the reflection spectrum of green plants is different from the inanimate soil background, and this characteristic can be used to distinguish them (Liu et al. 2013).

The current color models used for image processing are RGB, HIS, YCbCr, etc (Liu et al., 2012). The RGB color space is composed of three colors – red, green, blue as the primary ones (Fig. 1). The other colors are formed by mixing of three primary colors. The HIS color space is composed of hue, saturation, and brightness, and it is beneficial for human perception. The YCbCr color space is a relative value of a luminance signal Y and two-color difference signals: blue relative luminance B-Y and red relative luminance R-Y.

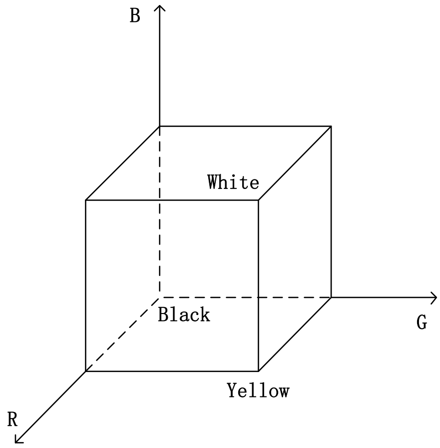

Fig. 1. Model of RGB color system.

1.3. Method of image segmentation

Segmenting the seedlings from the background is a key step in image processing, and the segmentation effect will affect the acquisition of location information by seedling recognition system (Zhou et al., 2013). The background segmentation of color image is generally achieved by grayscale and binarization. The green plants and the background soil have different characteristics in the three-color components of R, G, and B (Su et al., 2018). By separating the original image into three independent primary color dimensions, and then selecting different combinations of color features, each pixel in the image is converted, that can achieve the purpose of enhancing the contrast between the target crop and the background soil in the image. Since the original colored image is transformed into a grayscale image in this process, the combination of color features applied in the conversion is called the grayscale factor. According to the color characteristics, the most commonly used method is the extra green one, which makes use of characteristics that the twice of G value is greater than the sum of R and B values. The extra green method extracts the green plant image better. The shadow, withered grass and soil in the images can be more obviously suppressed, and the sunflower seedling is more visible in the images. In my research, two images of sunflower seedlings were selected. First image was taken in the dark outside environment (Fig. 2, A), and the second one was taken in the outside environment with strong sunlight (Fig. 2, B), so there were some shadows in the images. There were impurities in the soil background in the two images.

(A) Sunflower seedling 1 (B) Sunflower seedling 2

Fig. 2. Sunflower seedlings.

According to the characteristics of the Color eigenvalue of green crops in farmland, method of weighting grayscale image is adopted. The calculation formula is as follow (1) :

$$Gray(x,y) = w_1R(x,y) + w_2G(x,y) + w_3B(x,y) \quad (1)$$

$Gray(x,y)$ represents the gray value of pixels of (x,y) ; $R(x,y)$、$G(x,y)$、$B(x,y)$ are the three color components of the input RGB color images. w_1, w_2, w_3 denotes the coefficients of each component, their values are $w_1 = -1$, $w_2 = 2$, $w_3 = -1$, so the formula is showed as (2).

$$Gray(x,y) = 2G(x,y) - R(x,y) - B(x,y) \quad (2)$$

Using formula (2) to gray the image, the gray image is shown on Fig. 3.

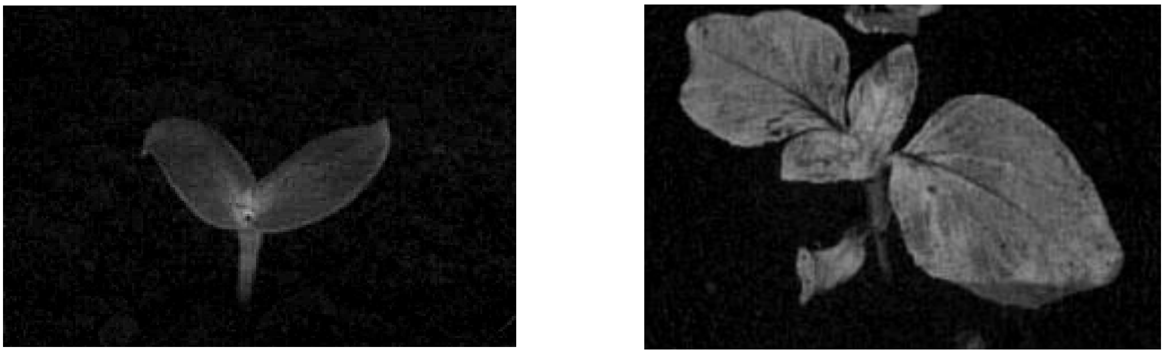

Fig. 3. Grayscale images.

The color image has been converted into a gray image after being processed by the grayscale factor. In this image, the difference between the gray value of the green plant and the gray value of the background soil is obvious. Therefore, the image threshold segmentation method can be used to achieve the recognition of green plants. Threshold segmentation methods include fixed threshold method and adaptive threshold method. The gray histogram of the two images are showed on Fig. 4.

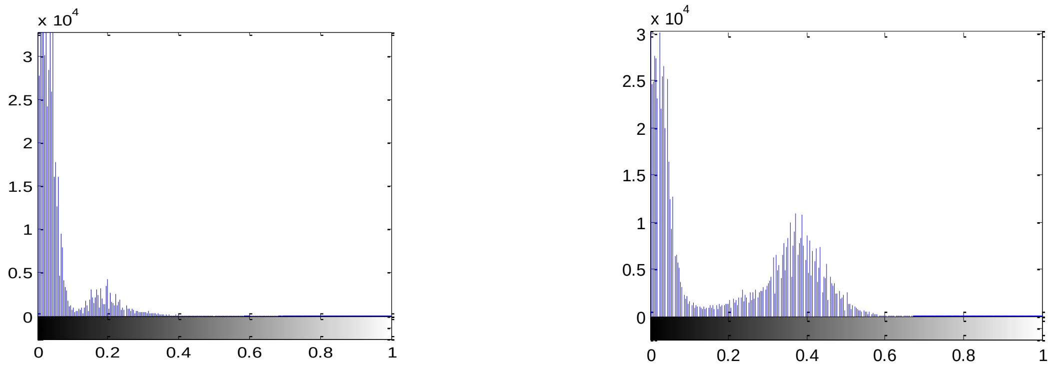

Fig. 4. Gray histogram of image.

The grayscale histogram has obvious bimodality and is suitable for thresholding, as long as the threshold is taken at the valley directly between the two peaks. Due to the influence of outdoor sunlight, the value at the trough is variable for each image, and a fixed threshold cannot be determined to segment the image. Therefore, in order to automatically identify sunflower seedlings, this study uses the maximum variance automatic threshold method. This method is an adaptive threshold method. Its calculation is simple and stable. The basic idea is to divide all the pixels in the image into two categories. The pixels less than the threshold T are called background pixels, and the pixels larger than the threshold T are called the target pixels. n_1 represents the number of background pixels, n_2 represents the number of target pixels, $m \times n$ represents the size of an image, θ_1 represents the proportion of the number of background pixels, θ_2 represents the number of target pixels after segmentation by threshold T. T represents the optimal segmentation threshold. The calculation formula is as follows:

$$\theta_1 = \frac{n_1}{m \times n}$$

$$\theta_2 = \frac{n_2}{m \times n}$$

$$n_1 + n_2 = m \times n \quad (3)$$

The gray value t is sequentially taken within the range of the minimum gray value to the maximum gray value, and the variance σ^2 is obtained, when the gray value $t = T$. The value of t at this time is the optimal segmentation threshold T. The formula for calculating the variance is as follows:

$$\sigma^2 = \theta_1 \times \left(\mu_1(t) - \mu_T(t)\right)^2 - \theta_2 \times \left(\mu_2(t) - \mu_T(t)\right)^2 = \theta_1\theta_2\left(\mu_1(t) - \mu_2(t)\right)^2 \quad (4)$$

$\mu_T(t)$ represents the total average gray level of the whole image, $\mu_1(t)$ represents the average gray level of background pixels, $\mu_2(t)$ represents the total average gray level of target pixels.

1.4. Algorithm design

According to the above analysis, this paper proposes a fast segmentation method based on farmland green crop image, the steps are follows:

(a) The image is divided into small pieces of a region; each sub region corresponds to a crop seedling.

(b) Pre-process each sub-piece, using the super green method ExG to get gray scale image.

(c) In order to reduce the influence of noise points on image segmentation accuracy, median filtering method is used to decrease noise in gray image.

(d) Automatic calculation of optimal threshold T by Ostu method. The gray value of each pixel is compared with the threshold value, and the pixel is divided into plant or background according to the comparison results.

(e) The white connected area of the identified plants is analyzed and located, ignore the scattered white areas. Using the method of regional feature extraction, calculate the centroid position of the largest polygon composed of plant regions, and mark the centroid position with small red circle in the image.

(f) If there are other sub-pictures untreated, skip to (b) to continue.

Results. In this experiment, sunflower images collected under different illumination conditions were used as materials (as shown in Fig. 1). The algorithm proposed in this paper was tested and verified. The identification and location of sunflower seedling images in farmland was solved.

The algorithm was implemented by MATLAB, and its version is r2014a. The operating system of the computer was Windows 10, the computer processor was Intel Core i5, and the memory capacity was 4G.

This method was used to recognize the sunflower seedling image (Fig. 2). The binarization segmentation result is shown on Fig. 5.

Fig. 5. Image segmentation results.

The results show that the sunflower seedlings in the image can be identified correctly by using the method of this paper, regardless of the illumination intensity and the interference of impurities in the soil background. After obtaining the integral binary image of sunflower seedling plant area, the centroid position of the largest polygon composed of plant area was calculated by region feature extraction method, and marked with small red circle. The marking result is shown on Fig. 6.

Fig. 6. Centroid of the crop image.

Discussion. 100 sunflower seedling images were taken for recognition, in order to verify the effectiveness of the algorithm, and compared with Cr color difference method in YCbCr color space. 10 representative images were extracted from 100 images for processing and analysis (Reference to table 1). The relative error rate was calculated by comparing the segmented seedling area with the actual area (Reference to table 2).

Tabel 1

Segmentation results of seedling area (Pixel)

Num	Extra Green	Cr	Manual caculation
1	2862	2792	2812
2	2571	2490	2550
3	1753	1660	1745
4	2855	2693	2812
5	1832	1776	1816
6	2800	2605	2720
7	2495	2346	2486
8	2865	2690	2800
9	2280	2170	2273
10	2250	2170	2240

Tabel 2

Relative error of segmentation (%)

Num	Extra Green	Cr
1	1.78	0.71
2	0.82	2.35
3	0.46	4.87
4	1.53	4.23
5	0.88	2.20
6	2.94	4.23
7	0.36	5.63
8	2.32	3.93
9	0.31	4.53
10	0.45	3.13

It can be seen from the result of table 2 that the segmentation effect of Extra Green with Ostu threshold segmentation method is better than that of color difference Cr with Ostu threshold one. It can eliminate the disturbance of soil background and light change to some extent, and can adapt to the growth environment of crop seedlings.

Conclusions. In our study, the identification and location of sunflower seedlings in farmland were researched. A fast segmentation method based on green crop image was proposed. It used color characteristics of green crops and background soil, and carried out gray scale and binarization of images. The segmentation and location of green crops from farmland images were realized, which provides scientific basis for the next step of seedling management.

The rate of emergence of a certain area in the farmland can be obtained and provide scientific guidance for supplementing and thinning seedlings. The experimental results showed that the algorithm can effectively extract and locate the green crop seedlings from the image, and realized the non-destructive measurement of crops.

References:

1. Hamuda, E., Glavin, M., & Jones, E. (2016). A survey of image processing techniques for plant extraction and segmentation in the field. Computers and Electronics in Agriculture, 125, 184–199.

2. Iqbal, Z., Khan, M. A., Sharif, M., Shah, J. H., ur Rehman, M. H., & Javed, K. (2018). An automated detection and

classification of citrus plant diseases using image processing techniques: A review. Computers and electronics in agriculture, 153, 12–32.

3. Nguyen, L. H., Zhu, J., Lin, Z., Du, H., Yang, Z., Guo, W., & Jin, F. (2019, April). Spatial-temporal multi-task learning for within-field cotton yield prediction. In Pacific-Asia Conference on Knowledge Discovery and Data Mining, Springer, Cham, 343–354.

4. Lei Yaping, Han Yingchun, Wang Guoping, Feng Lu, Yang Beifang, fan Zhengyi, Wei Xiaowen, Wang zhanbiao, Zhi Xiaoyu and Xiong Shiwu (2017). Low altitude digital image diagnosis technology of cotton seedling by UAV. China Cotton, 5, 23343–354. 25

5. Zhang Meina, Feng Aijing, zhoujianfeng and lvxiaolan (2019). prediction of cotton yield based on visual and spectral images collected by UAV. (English). "Journal of Agricultural Engineering (5), 11.

6. José M. Peña, Jorge Torres-Sánchez, Angélica Serrano-Pérez, Ana I. de Castro and Francisca López-Granados (2015).Quantifying efficacy and limits of unmanned aerial vehicle (UAV) technology for weed seedling detection as affected by sensor resolution. Sensors (Basel, Switzerland), 15(3), 5609–5626.

7. Di Gennaro, S. F., Toscano, P., Cinat, P., Berton, A., & Matese, A. (2019). A precision viticulture UAV-based approach for early yield prediction in vineyard. In Precision agriculture'19, Wageningen Academic Publishers, 370–378.

8. Filippi, P., Whelan, B. M., Vervoort, R. W., & Bishop, T. F. (2020). Mid-season empirical cotton yield forecasts at fine resolutions using large yield mapping datasets and diverse spatial covariates. Agricultural Systems, 184, 102894.

9. Tedesco-Oliveira, D., da Silva, R. P., Maldonado Jr, W., & Zerbato, C. (2020). Convolutional neural networks in predicting cotton yield from images of commercial fields. Computers and Electronics in Agriculture, 171, 105307.

10. Samiei, S., Rasti, P., Vu, J. L., Buitink, J., & Rousseau, D. (2020). Deep learning-based detection of seedling development. Plant Methods, 16(1), 1–11.

11. Jiang, Y., Li, C., Paterson, A. H., & Robertson, J. S. (2019). DeepSeedling: deep convolutional network and Kalman filter for plant seedling detection and counting in the field. Plant methods, 15(1), 1–19.

12. Feduck, C., McDermid, G. J., & Castilla, G. (2018). Detection of coniferous seedlings in UAV imagery. Forests, 9(7), 432

13. Quan, L., Feng, H., Lv, Y., Wang, Q., Zhang, C., Liu, J., & Yuan, Z. (2019). Maize seedling detection under different growth stages and complex field environments based on an improved Faster R–CNN. Biosystems Engineering, 184, 1–23

14. Khirade, S. D., & Patil, A. B. (2015). Plant disease detection using image processing. In 2015 International conference on computing communication control and automation IEEE, 768–771.

15. Singh, V., & Misra, A. K. (2015). Detection of unhealthy region of plant leaves using image processing and genetic algorithm. In 2015 International Conference on Advances in Computer Engineering and Applications IEEE, 1028–1032.

16. Pujari, J. D., Yakkundimath, R., & Byadgi, A. S. (2015). Image processing based detection of fungal diseases in plants. Procedia Computer Science, 46, 1802–1808.

17. Oo, Y. M. & Htun, N. C. (2018). Plant leaf disease detection and classification using image processing. International Journal of Research and Engineering, 5(9), 516–523.

18. Zhang Yibin & Gu Linling (2018). Global sunflower planting area and pesticide market and varieties in recent years. modern pesticide 17(01), 16–18.

19. Yinjianjun, Shenbaoguo & Chen Shuren (2010). Field weed localization technology based on machine vision. Journal of agricultural machinery, 41(06), 163–166+192

20. Gong Lixiong (2014). Crop image recognition based on COM VI and double threshold Otsu algorithm. Journal of drainage and irrigation machinery engineering, 000(004), 363–368.

21. Chen Xiaobang, Zuo Yayao, & Wang Mingfeng (2019). A method of crop image recognition by UAV. Cn109241817a

22. Tian Haifeng, Wu Mingquan, Niu Zheng, Wang Changyao, & Zhao Xin (2015). Recognition of upland crops under complex planting structure based on radarsat-2 image. Acta AGRICULTURAE engi neering Sinica, 31(023), 154–159.

23. Sun Ming & Ling Yun (2002). Automatic recognition technology of radish seedling based on computer vision. Journal of agricultural machinery, 05, 75–77.

24. Wang sile, Yang Wenzhu & Lu sukui (2015). Identification methods of green plants in the monitoring image of crop growth in field. Jiangsu Agricultural Sciences, 43(11), 487–492.

25. Ke Qiuhong, Zhang Junmei & Tian Ye (2013). Fast extraction of green plants from digital images. Computer applications and software, 30(10), 266–268 + 283.

26. Zhang Zhibin, Luo Xiwen, Hou Fuxiang & Xu Xiaodong (2010). A fast segmentation algorithm for ridge and row structures based on color features. 2010 International Conference on Agricultural Engineering, Shanghai, China.

27. Wang Xue & Guo Xinxin (2018). The method of green crop segmentation based on GR color characteristics. Heilongjiang Science, 9(16), 14–15 + 19

28. Liu Lijuan, liuzhongpeng and Cheng Fang (2013). Study on image recognition and preprocessing of maize leaf disease during growing period. Henan Agricultural Science, 42(10), 91–94.

29. Liu Liqiang, Xiang Jianting and Wu Zequan (2012). Research on rapid identification method of healthy seedlings based on color features. Agricultural science and technology and equipment, 06, 26–28.

30. Zhou Jun, Wang Mingjun & Shao Qiaolin (2013). Adaptive segmentation method of green plants in farmland image. Journal of agricultural engineering, 29(18), 163–170.

31. Su Boni, Hua Xiyao & Fan Zhenqi (2018). Research on image segmentation of rice diseases based on color features. Computer and Digital Engineering, 08, 1638–1642.

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РОЗПІЗНАВАННЯ ТА ЛОКАЛІЗАЦІЯ СХОДІВ СІЛЬСЬКОГОСПОДАРСЬКИХ КУЛЬТУР НА ОСНОВІ АНАЛІЗУ ЦИФРОВИХ ЗОБРАЖЕНЬ

З розвитком цифрових технологій можна з легкістю отримати велику кількість зображень сільськогосподарських угідь. Завдяки ефективному аналізу таких цифрових зображень, ми отримуємо інформацію стосовно темпів росту сільськогосподарських культур, що може покращити сільськогосподарське виробництво. Ефективність традиційного моніторингу росту культур невисока, особливо на великих сільськогосподарських угіддях, оскільки такий моніторинг займає багато часу. Штучний метод обмежує своєчасність прийняття наукових рішень щодо необхідності обробки сільськогосподарських угідь. Прогресивні цифрові технології та технології обробки зображень відкривають новий спосіб моніторингу, який не завдає шкоди сільськогосподарським культурам. Результати аналізу зображень можуть допомогти агровиробникам швидко і точно оцінювати темпи росту культур, що сприятиме прийнятю швидких та ефективних управлінських рішень. Об'єктом дослідження є отримані зображення сходів соняшнику на сільськогосподарських угіддях. Основний зміст дослідження полягає у розпізнавані зелених сходів на ґрунтовому фоні. Запропоновано метод розпізнавання сходів соняшнику на основі зонації ділянок за кольором і методу Оцу для обчислення порогового зображення. Цей метод простий у застосуванні та може бути пристосований для сегментації зображень сільськогосподарських угідь, що закладає основу для процесу локалізації таких культур. Ґрунтуючись на результатах розпізнавання зображень, завдяки алгоритму сходи культур можуть бути локалізовані. Завдяки швидкій ідентифікації сходів соняшнику, можна визначити ділянки із прогалинами, де зійшли не усі саджанці. Або навпаки, визначити ділянки із ущільненими сходами, де кількість сходів потрібно зменшити. Алгоритм забезпечує основу для точного управління. Отримані результати показують, що алгоритм із компонентом визначення зеленого кольору може швидко та ефективно ідентифікувати сходи соняшнику на ґрунтовому фоні та на основі розпізнавання зображень локалізувати такі сходи. Цей алгоритм не чутливий до вологості ґрунту та умов освітлення, а також менше схильний до впливу залишкового покриву угідь, тому він може застосовуватися до різних типів ґрунту. Окрім цього, такий метод є прикладом неруйнівного моніторингу сходів соняшнику.

Ключові слова: *сегментація зображення; машинний зір; колірні ознаки; визначення зеленого кольору; адаптивний метод порогової обробки зображень.*

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