A lawn weed detection in winter season based on color information

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Abstract

In this work, we propose a lawn weed detection method based on simple and fast color image processing for the case that color of weeds and lawns are clearly different, especially in winter. The proposed detection method is evaluated with two types of simulated automatic weeding systems, i.e., chemical and non-chemical (pulse high voltage discharge) based system. For chemical based, the detection method can destroy weeds of more than 91.48% with correct spray rate of 93.22% and herbicide reduction rate of 93.72%. For non-chemical based, 70.21% of weeds can be destroyed with 98.18% of sparking accuracy; only 3 times of false sparking. From the results, the performances of the proposed method are better than those of conventional gray-scale based detection methods when detects weeds in winter dataset. We also propose a method for deciding from an input image whether the color information based method should be employed. By testing with four image datasets taken from four different seasons, this method can completely discriminate winter dataset from the others. Consequently, a hybrid method, i.e., a combination between a gray-scale based detection method and the color based method, can be realized.

1. Introduction

Due to environmental pollutions and economics concerns, reduction of using herbicide for controlling weeds in agriculture fields, lawn fields, or golf course is preferred. Presently, an automatic weed control or automatic weeding system that employs image processing techniques becomes an alternative solution for controlling weeds. Such a system uses a camera to capture lawn image and processes the captured image for detecting the area of weeds. Then the system controls a nozzle system for selective spraying (sometimes called spot spraying), i.e., it sprays herbicide only on the area of detected weeds. This leads to significant reduction of herbicide usage. Moreover, an automatic non-chemical weeding system, e.g., using an electric spark discharge for destroying weeds, also becomes applicable.

For weed detection in agriculture fields, color information is often used as a feature for discriminating plants (crop and weed) from backgrounds because of the difference in the color of plants and backgrounds [4, 5, 7, 13]. However, most lawn weeds detection methods extracts features from gray-scale or edge images, and avoids using any color information [3, 9-12], because the color of weeds and lawns are similar, especially in spring, summer, and autumn. On the contrary, in winter, colors of some types of lawns become yellow, brown, or gray while color

of weeds are still green, yellow green, or become red for some species. Due to this difference, color information can be exploited to make the system more efficient and simple.

Up to now, there are a few lawn weed detection methods that employ color information. In [6], Kawamura et al. developed a method for detecting ears of weeds which form in spring and have different color from lawns. Obviously, this method cannot detect weeds which have no ears. In [8], Mashita et al. reported about development of a method using difference of intensity of red band between weeds and lawns for detecting in winter. However, these works lack an obvious explanation about their methods and experimental results.

For agricultural applications, Woebbecke et al. investigated the methods using color indices, e.g., r-g, g-b, or 2g-r-b (excess green), modified hue, and green chromatic coordinate for distinguishing weeds from various non-plant backgrounds, i.e., wet soil, dry soil, wheat and corn residues [4]. They reported that excess green index and modified hue accurately distinguished weeds from the backgrounds but modified hue was computationally intense. Because excess green index was designed to discriminate green weeds from the backgrounds, it can not be employed for detecting weeds in lawn fields which contain, as mentioned before, green, yellow-green, and red weeds.

In this work, we propose a simple and fast color based method for detecting lawn weeds when the color of weeds and lawns are clearly different, especially in winter. We also propose a method for selecting images of such situation for which the color based method should be applied. This makes a hybrid detection method, i.e., a combination between a gray-scale based method and the color based method, can be realized. The hybrid method can selectively employ the appropriate method for detecting weeds depend on an input image. If color of weeds and lawns in the image are different, it selects the color based method which is more accurate and faster to detect weeds. Otherwise, it selects the gray-scale based method.

2. Color Based Weed Detection Method

According to our observation of lawn weed images in winter, the colors of weeds may be green, yellow-green, or red while the color of lawns may be yellow, brown, or gray, and is quite brighter than that of weeds. Moreover, lawn areas contain some dark areas that are caused by the shadow of grass blades. Depend on these observed characteristics, we set the following rules for discriminating the area of weeds from lawns:
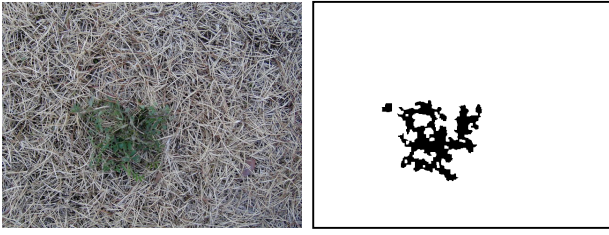
Figure 1. Weed detection result of the proposed method.

Figure 2. Example of images from each datasets. Top-left: dataset 1, top-right: dataset2, bottom-left: dataset 3, and bottom-right dataset 4.

1) The color of weeds should be green or yellow green or red, i.e., the difference between values of green band and red band has to satisfy one of the next inequalities.

$$G(x, y) - R(x, y) > Th_{y-g} \qquad (1)$$

$$R(x, y) - G(x, y) > Th_r \qquad (2)$$

From the above inequalities, $G(x, y)$ is the intensity value of green band, and $R(x, y)$ is that of red band.

2) The intensity of weed areas should be more than a threshold value Th_{dark}, and should be less than a threshold value Th_{bright}.

$$Th_{dark} < Avg(x, y) < Th_{bright}, \qquad (3)$$

$$Avg(x, y) = \frac{R(x, y) + G(x, y) + B(x, y)}{3}, \qquad (4)$$

where $R(x, y)$, $G(x, y)$, and $B(x, y)$ are the intensity value of red, green, and blue bands, respectively. In this work, we set $Th_{y-g} = 5$, $Th_r = 35$, $Th_{dark} = 50$, and $Th_{bright} = 130$.

After selecting the areas satisfied the above rules, small area deletion and closing operations are applied for removing noise areas. The example results of weed detection are shown in Fig. 1.

3. Winter Lawn Image Discrimination

In order to design the automatic weeding system which can automatically select the appropriate method for each season, a calendar program may be integrated to the system. Consequently, the system uses the appropriate method programmed in the calendar. This way seems possible if the system operates in the middle of winter. However, a problem may be occurred when the system operates in the beginning or the end of winter because the color of lawns may not completely change. In fact, changing of season of each year may not occur at the same period, and is different depending on zone. Therefore we cannot accurately predict the date that the entire of lawn area change from green into yellow or change back from yellow to green. For example, let's set the calendar program so that the system chooses the color based method from 1st December to 1st March. What happens if the system operates on 1st December and the color of lawn has not changed to yellow yet? The answer is that the system falsely detects lawn areas as weeds areas and causes a lot of errors. The same result will occurred if the system operates on 1st March and the color of lawn has changed back to green already.

One may say that the system does not need such calendar program but appropriate method should be selected by a user. However, in the case that color of lawn does not change uniformly, i.e., colors of some areas have changed to yellow while those of the other areas are still green, has the user to consider one by one image and decide for which method should be applied for? That is hardworking. Otherwise, the user has to select the gray-scale based method and use it for the entire area to make sure that a great number of errors will not occur but this means that the system cannot efficiently operate. Therefore, the system needs an adaptive detection to give the best result. Moreover, this method makes the system move nearly to a full automatic system that does not need any decision by the user.

The winter image discrimination method is described as follow:

1) Segment for green area from an input image and convert it into a binary image $bi(x, y)$ by using the next equation. Zero-pixels are expected as green pixels.

$$bi(x, y) = \begin{cases} 0 & , if\ G(x, y) - R(x, y) > 15 \\ 1 & , otherwise \end{cases} \qquad (5)$$

2) Divide the binary image into small blocks. Here, block size is 80 × 80 pixels.

3) Count the number of zero-pixels in each block. If the number of zero-pixels is less than a threshold value Th_1, that block is called non-green block. In this work, we set the threshold Th_1 equal 1% of block area.

4) Count the number of non-green blocks in the entire image. If the number of non-green blocks is greater than a threshold value Th_2, the image is considered as winter lawn image.

The above discrimination method directly analyses RGB color image without any transformation to another color model, e.g., HSV model. Although analysis in the other color models is also possible, this method is fast and

simple. This is an important point that we have to consider because the discrimination method has to be done before doing weed detection for every image. If the discrimination method is computationally intense, the weeding system will spend a lot of time for weeding.

Moreover, one may say that more simple method is counting non-green pixels instead of counting non-green blocks. However, such method will suffer from the size of green weeds because it does not consider any spatial information while the latter one considers. Let's suppose a winter image containing the large green weeds and another image containing no weeds but was taken before the color of lawn will completely change to yellow. In the first image, green pixels locate in the compact area. However, in the second image, green-pixels, i.e., grass blade areas which have not yet changed to yellow, spread in the entire image. If we assume that there are the same numbers of green pixels in the two images. Counting non-green pixels cannot distinguish the difference of the two images while our proposed method can do.

4. Experimental Results and Discussions

4.1. Performance of simulated weeding systems

The proposed color information based weed detection method, denoted by Color, is compared with three of gray-scale based method, i.e., Bayesian classifier based method (BC) [12], morphology operations based method (MO) [11], and gray-scale uniformity analysis based method (UA) [9]. The dataset used in the experiments is the dataset 3 used in [12]. This dataset was collected in winter (4th January 2006) when the color of lawns completely changed into yellow. Images were taken from top-view with about 39 cm distance from camera to lawn. Image size is 640 × 480 pixels, covering a lawn area about 274× 205 mm. The dataset contains 30 images; five images were used as training set for BC method and 25 images were used as test set. Performance evaluations were done by using two-type of simulated automatic weeding systems. The first is chemical based weeding system. The second is non-chemical based weeding system which using pulse high voltage discharge for destroying weeds [1, 2]. The simulation conditions and parameters of three gray-scale method were the same as in [12]. For the proposed method, structuring element of closing operation is square of size 5 × 5 while small area deletion threshold is set to 10 and 110 for chemical and non-chemical based system, respectively. Note that, for non-chemical based system, the BC method needs a noise removal step, i.e., closing and small area deletion operations, so it is denoted by BC NR. The results of simulation were shown in Tables 1 and 2.

4.2. Winter dataset discrimination result

For this experiment, we used the winter dataset used in the previous experiments and three non-winter datasets, i.e., dataset 1, 2, and 4, used in [12]. The dataset 1 was taken on 18th June 2005 (summer), the dataset 2 on 4th October 2005 (autumn), the dataset 3 on 4th May 2006 (spring). Each dataset contains 30 images, was taken under the same conditions as the dataset 3. So the total number of images we tested is 120. Example of images

from each datasets is shown in Fig.2.

In this experiment, we calculate the number of minimum and maximum of non-green blocks. The result was shown in Table 3.

Table 3.   Number of non-green blocks

Dataset	Minimum number of non-green blocks	Maximum number of non-green blocks
1	0	9
2	0	2
3	28	48
4	0	25

4.3. Computational time

We evaluate computational times of each detection methods and the winter image discrimination method. The evaluation was done on Pentium IV 1.6 GHz. PC. Table 4 shows the comparison of their computational times.

Table 4.   Computational time

Method	Computational time (sec.)
BC / BC NR	0.206 / 0.268
MO	0.412
UA	0.405
Color	0.068
Winter image discrimination	0.010

4.4. Discussions

From Table 1, i.e., chemical based system, the proposed color based method leads the other methods in weed destruction (# of killed weeds and killed weed rate). It could destroy 43 weeds from total 47 weeds, i.e., miss only 4 weeds, with good accuracy (# of correct sprayed blocks and correct spray rate). With the good trade-off between these two points, the proposed method can be considered as the most appropriate method for this case. Although the UA and MO methods gave slightly better in accuracy and herbicide reduction rate, it can not compared with the proposed method in weed destruction performance.

From Table 2, i.e., non-chemical based system, the proposed method also leads the others in weed destruction performance, 70.21% of killed weed rate. For this case, the major factor has to be considered is the number of false spark and false spark rate because false sparking on lawn means the lawn receives damage and becomes withered. From this point, the BC, UA, and proposed methods could accurately apply spark discharges to weeds, i.e., numbers of false sparks were 2-4 times and false spark rates were less than 6%. For this case, the proposed method can also be considered as the best method due to its good trade-off between weed destruction and accuracy performances.

From Table 3, we can see that the images in the dataset 3 (winter dataset) contain a lot of non-green blocks. That means lawn color already changed into yellow. Among 30 images in the dataset 3, the minimum number of non-green blocks is 28 while those of the other datasets were 0. In contrast, maximum numbers of non-green blocks of the other datasets were less than the minimum number of non-green blocks of the dataset 3. Obviously, if we choose the threshold value Th_2 equal 25, 26 or 27, all

images in the dataset 3 (winter dataset) can be completely discriminated from the other datasets.

From Table 4, computational times of winter dataset discrimination method is only 0.01 seconds. This number is very short and does not affect the computational time of detection method so much. Therefore the results from all experiments show the feasibility of using the proposed color based weed detection and winter lawn image discrimination methods to construct a hybrid system between color and gray-scale based methods which automatically employs the appropriate detection method depend on an input image.

5. Conclusion

In this work, we proposed the color information based method for detecting weeds in winter which the color of weeds and lawns are clearly different. The performances of simulated weeding systems of the proposed method were better than those of the other gray-scale based methods. Moreover, we also proposed the method for discriminating winter images from the images of other seasons. The method gave the completely accurate result of discrimination. By using both of proposed methods, the hybrid automatic weeding system which automatically employs the appropriate method can be realized.

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Table 1.   Performance of simulated chemical based weeding system

Method	Dataset 3 (total number of weeds = 47, number of weed blocks = 1346)							
	# of killed weeds	Killed weed rate	# of sprayed blocks	# of correct sprayed blocks	# of false sprayed blocks	Correct spray rate	False spray rate	Herbicide reduction rate
BC	38	80.85%	1231	1006	225	81.72%	18.28%	92.3%
MO	30	63.83%	993	931	62	93.76%	6.24%	93.79%
UA	17	36.17%	532	507	25	95.30%	4.70%	96.67%
Color	43	91.48%	1004	936	68	93.22%	6.77%	93.72%

Table 2.   Performance of simulated non-chemical based weeding system

Method	Dataset 3 (total number of weeds = 47)						
	# of killed weeds	Killed weed rate	# of spark	# of correct sparks	# of false sparks	Correct spark rate	False spark rate
BC NR	26	55.32%	98	94	4	95.92%	4.08%
MO	30	63.83%	97	84	13	86.60%	13.40%
UA	15	31.91%	37	35	2	94.59%	5.41%
Color	33	70.21%	165	162	3	98.18%	1.81%