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RICE PLANT DETECTION IN HEADING TERM FOR AUTONOMOUS ROBOT NAVIGATION

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ABSTRACT Our objective in this research is to develop a method to detect rice plant in image of paddy field during heading term. It is essential for autonomous robot navigation on levee in paddy field to distinguish between rice plant and weed because the robot must be able to judge whether a domain in the field is travelable or not. Nevertheless, distinction between rice plant and weed is a challenging problem because colors of them are very similar. We address paddy field in heading term and focused on pattern that is formed by rice ears in the image. Our proposing method uses rice ears as a clue to the rice plant detection. The sequence is as follows. Firstly, rice ears in the image are extracted by using simple threshold method. The rice ears form a discriminative pattern in the rice plant domain of the image. Meanwhile, in the weed or levee domain, some pixels are also extracted but they form different pattern. Secondly, we detect the ears' pattern by calculating moment. The moment is calculated by using window which is moved in the image. Finally, rice plant domains are detected by evaluating moment values. We used a number of images taken from paddy fields by digital camera and assessed the effectiveness of our method. Our method worked well on certain condition, but there were some failure cases. We discuss about further improvements.

Keywords: Image processing, Rice plant detection, Rice ear, High-order moment

INTRODUCTION Autonomous robot and autonomous vehicle have potential to become a useful tool for agriculture. They are able to be used not only for conventional agricultural tasks such as seeding, fertilizing, harvesting, but for new agricultural operations such as crop growth monitoring, disease damage monitoring, insect damage monitoring, and so forth. To realize autonomous robot system for agriculture, there are still many problems to be solved, and various kinds of techniques are needed to be combined. For autonomous robot, it is a fundamental function to judge whether a domain in the field is travelable or not. Especially for autonomous robot navigation on levee in paddy field, major non-travelable domain is rice plant domain. In this research, we address paddy field in heading term and discuss about how to detect rice plant in rice field images. Researches about clop centerline detection (H. Zang, et. al., 2008, S. Han, et.

al., 2003) and about guidance for harvester by image processing (E. R. Benson, et al., 2003) were reported. In the cases treated in those researches, crops had remarkable color (including gray scale) feature by comparison with the soil and therefore, these information can directly be used as the clue to the object detection. In contrast, color feature of rice clop and that of levee are often similar because of weeds on the levee. Our objective in this research is to propose a method to detect rice plant domain on paddy field images. In our method, rice ears are used as a clue to the rice plant detection. Rice ears constantly exist on rice plant domain in the images and they form discriminative pattern. The first step of our method is to extract rice ears in the image. After extracting rice ears, feature quantities are calculated for each pixel by using small window including the pixel. Area and high-order moments of the pixels in the window were tested as the feature quantities. Finally, the image was divided into small square compartments and detection of rice plant domain was executed for each compartment. Our method is intended to be used for coarse detection and to be used in combination with other methods for actual robot navigation. Because outdoor environments are so complicated and unstable, several kinds of method are needed to be used in combination for safe and stable navigation. Huang, et. al. (2009) proposed a pass planning method for outdoor mobile robot. There the terrain cost was firstly estimated per pixel, then expanded horizontally in terms of robot width. In our method, detection of rice plant domain is finally executed for small square compartments in the image because our method is based on pattern that is formed by rice ears and the purpose is coarse detection.

MATERIALS AND METHODS Our method of rice plant detection is consist of three sequences. 1) Extracting rice ears from the image, 2) calculating feature quantities per pixel, 3) Dividing the image into small square compartments and discriminating each compartment whether it belongs to rice plant domain or not. In this section, detail of each sequence is explained. Paddy field images used in this research were taken in Nantan City, Kyoto, Japan. Images were taken by digital camera (DSC-W170, Sony Corporation) and used after transforming to BMP format 24bit RGB, 640*480 size images.

Rice ear extraction Firstly, rice ears were extracted from the image. Criterion for the extraction was manually decided by trial and error. The criterion is as follows.

$$G > 150 \wedge G - R < 30 \wedge G - B > 80 \quad (1)$$

Where, R, G, and B represent 8bit depth of BMP R, G, B, respectively.

Figure 1. An example of rice ear extraction. Left: Source image. Right: Result of rice ear extraction.

Figure 1 shows an example of rice ear extraction. The extracted rice ears are represented as white pixels in the left image of figure 1. As seen in figure 1, the rice ear extraction is not so accurate and some pixels that are not of rice ears are extracted. But the purpose of the extraction is to use it for detecting rice plant domain, so the accuracy is not severely required for our purpose.

Feature quantities calculation Secondly, feature quantities were calculated for each pixel. The feature quantities for one pixel were calculated by using small window. The window was set so that it have the pixel at the center. We tested two types of value as feature quantity. One was area of extracted rice ears. For the convenience of visualizing the results, the area of extracted rice ears for one pixel, denoted by *A*, was defined for the result values to be between 0 and 255. *A* is defined as follows.

$$A = 255 \times \frac{N_{ear}}{W_{width} \times W_{height}} \tag{2}$$

Where, N_{ear} is number of extracted pixels in the window, W_{width} is width of the window, and W_{height} is height of window. Both W_{width} and W_{height} were set 40 pixels. The other feature quantity was high-order moment of extracted rice ears. In this research, the moment of order (m+n) for one pixel, denoted by $M_{m,n}$, is defined as follows.

$$M_{m,n} = 255 \times \frac{\sum_{x,y} (x - cgx)^m (y - cgy)^n I(x,y)}{\max\left(\sum_{x,y} (x - cgx)^m (y - cgy)^n I(x,y) \right)} \tag{3}$$

Where, *x*, *y* are coordinates of pixels in the image, *cgx*, *cgy* are coordinates of center of gravity of the extracted pixels in the window, $I(x,y)$ is 1 if a pixel is extracted one and 0 if otherwise. Sum is calculated by all pixels in the window. Maximum is obtained from all pixel values in one image. As in the case of N_{ear}, $M_{m,n}$ is defined for the result values to be between 0 and 255. As for calculation of $M_{m,n}$, W_{width} was set 60 pixels and W_{height} was set 40 pixels.

Rice plant domain detection Finally, the image was divided into small square compartments and each compartment was discriminated whether it was on rice plant domain or not. The size of each compartment was 40 pixels by 40 pixels. The discrimination was executed by using feature quantities of pixels in the compartment. We tested several kinds of criterion for discrimination, for example, by using maximum value of feature quantities, by using average value, by changing order of moment, by changing threshold, and so forth. In this paper, we present two criteria. The first criterion used area of extracted rice ears, *A* (see formula (2)). The value of *A* indicates how many pixels were extracted in the window, so it can be an evidence of rice plant domain. Criterion with the value of *A* was as follows.

$$20 < \max(A) < 90 \tag{4}$$

Where, maximum is obtained from all *A* values of pixels in the compartment. We express this criterion by 'C1' in this paper. The second criterion used moment of order (3+0), $M_{3,0}$ (see formula (3)). Moment represents some geometrical feature, so moment is expected to detect some difference between pattern formed by rice ears and pattern formed by pixels that are mistakenly extracted from non rice plant domain. By trial and error, we selected order (3+0) because it stably gave good result in comparison with other tested orders. Criterion with the value of $M_{3,0}$ was as follows.

$$SD(M_{3,0}) > 15 \tag{5}$$

Where, $SD(M_{3,0})$ is standard deviation of $M_{3,0}$ values of pixels in the compartment. We express this criterion by 'C2' in this paper.

RESULTS AND DISCUSSION Figure 2 shows results of detection for an image. In figure 2, Upper left image is source image. Upper right image shows result of rice ears extraction. Extracted rice ears are represented as white pixels. Lower left image in figure 2 shows result of rice plant domain detection by criterion C1 and lower right image shows result of rice plant domain detection by criterion C2. In lower two images, detected rice plant domain are represented as black compartments. In this case, rice ear extraction was successfully done and detection was good as for both criteria. The result by C1 and the result by C2 were a little different, but as previously noted, our method is intended to be used for coarse detection. In the viewpoint of coarse detection, both results are acceptable.

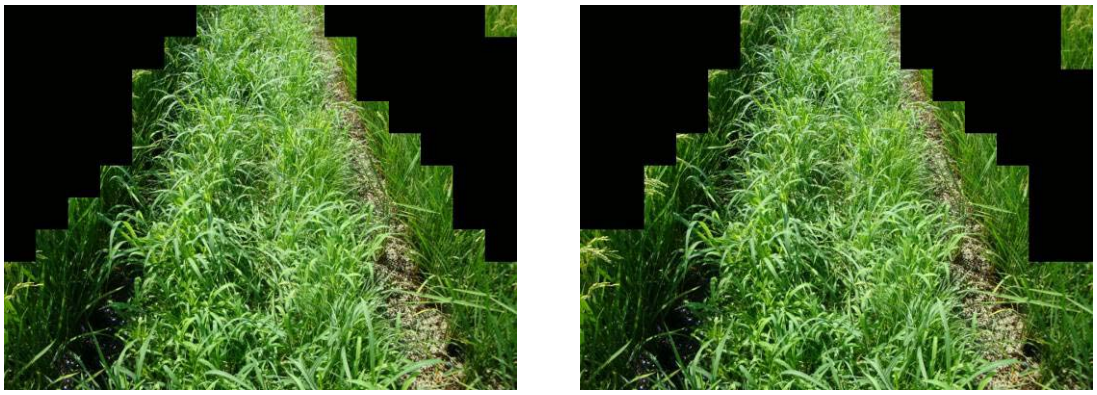
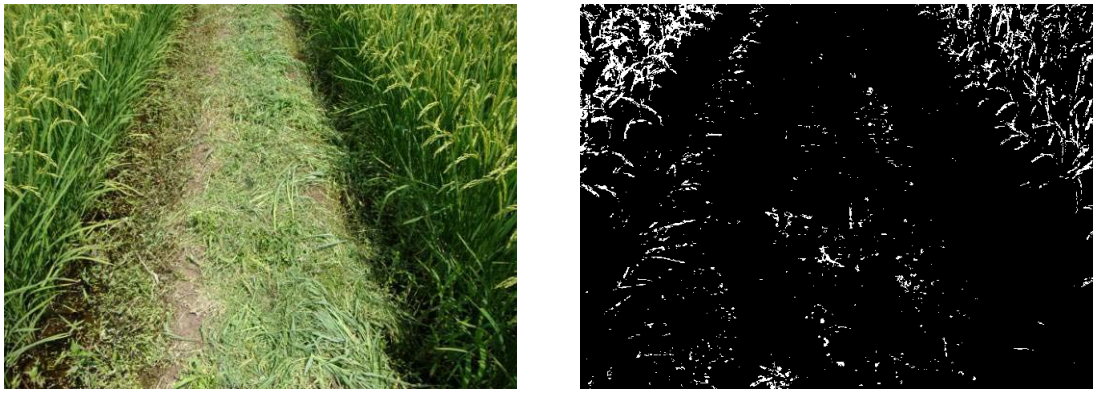


Figure 2. Results of Rice plant detection (1). Upper left: Source image. Upper right: Rice ear extraction. Lower left: Rice plant domain detection by criterion C1. Lower right: Rice plant domain detection by criterion C2.

Figure 3 shows results for another image. In this case, many pixels in the levee domain were extracted. Besides, ears were rather strongly extracted in the upper left part of the source image. Criterion C1 only uses area of extracted rice ears *A*. Therefore the detection method with C1 didn't work well. On the other hand, criterion C2 uses moment of order (3+0) $M_{3,0}$, and the result is improved in comparison with the result by C1 as shown in figure 3. It means that moment $M_{3,0}$ could successfully represent geometrical feature of pattern formed by rice ears. Although criterion C2 was better than C1 for the image shown in upper left of figure3, there was an 'isolated' false detection compartment. Such kind of false detection will be able to be modified by comparing with its neighbourhood compartments.



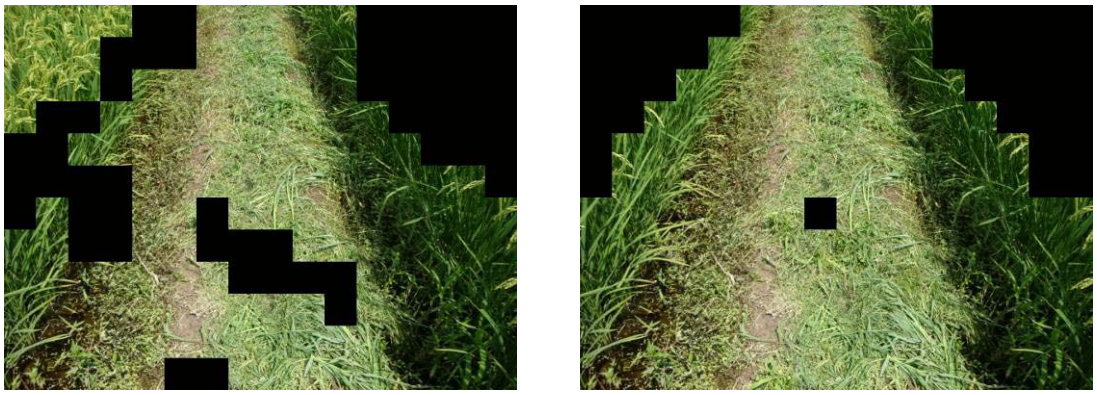


Figure 3. Results of Rice plant detection (2).

In the case shown in figure 4, criterion C2 functioned better than C1 as with the case shown in figure 3, but there were some 'clusters' of false detection compartments. We used moment to distinguish between the pattern formed by rice ears and the pattern formed by extracted pixels in the non rice plant domain, but pixels in the non rice plant domain could sometime form similar patterns to the pattern formed by rice ears in terms of moment. So some clusters of false detection compartments often appeared in an image. If such false detection (and false reject, as well) clusters are small enough, they will also be able to be modified by comparing with their surrounding compartments. We just tested area and moments of the extracted pixels as feature quantities in this research. To improve accuracy of the detection radically, another kind of feature quantities that can be used to distinguish the pattern of rice ears more strongly might be needed. Besides, improvement of the accuracy of rice ear extraction may also be helpful.

Figure 4. Results of rice plant detection (3).

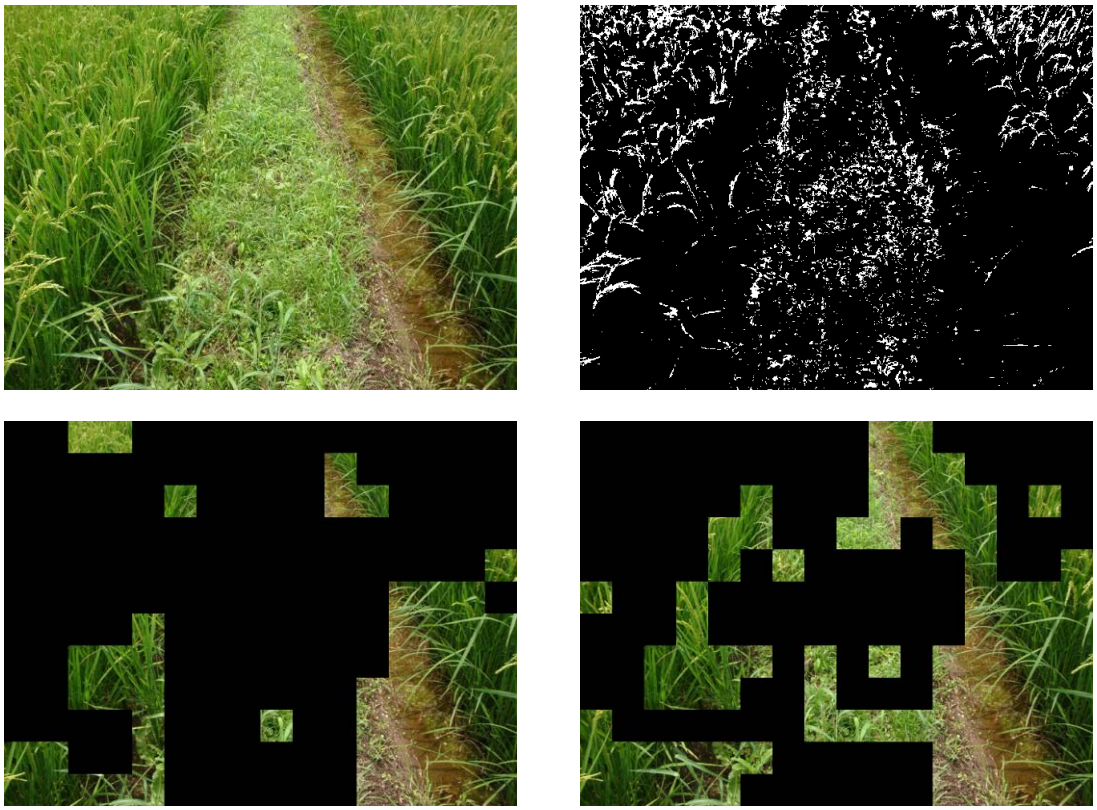


Figure 5. A case of detection failure.

Figure 5 shows a case of detection failure. Both C1 and C2 didn't work well. As seen the upper right image of figure 5, many pixels in the non rice plant domain were extracted and they formed similar pattern to that of rice ears. In the source image shown in figure 5, the color of the weeds was very similar to the color of rice ears. Indeed, many other images with the same kind of weeds as shown in figure 5 led to failure detection. Although criterion C2 didn't function, we could find some differences of texture between rice ears and pixels of the weeds. If we find some feature quantities that can describe the texture difference, we can make our method more practicable. In this research, we didn't take distance to each rice ear into account. The results showed that the distance has not significant influence from the viewpoint of coarse detection. For autonomous robot navigation, path planning method is needed. Our method of coarse rice plant domain

detection will be used to define ROI for path planning. Once rice plant domain is coarsely detected, path planning algorithm has only to treat the remainder of the image.

CONCLUSION We proposed a method of rice plant detection in the paddy field images by using rice ears. Our method is for coarse detection which can be of assistance to autonomous robot navigation. The method functioned well on certain condition, but it was still not satisfactory for actual use. Especially, performance of our method was strongly influenced by type of weed. We used area of extracted rice ears and moment of rice ears as feature quantities and tested two types of criterion for rice plant domain detection. Criterion using moment $M_{(3,0)}$ showed relatively good performance, but it wasn't enough to treat extensive paddy field images. To improve quality of the detection and make our method practicable, other kind of feature quantities and criterion that can describe the geometrical feature and the textural feature of extracted rice ears is needed.

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