

A Digital Image Processing-Based Automatic Method for Measuring Rice Panicle Lengths

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***Abstract.** This paper presents a new method based on digital image processing techniques such as color transformations and mathematical morphology, as well as on some specialist knowledge, to provide estimates for the lengths of rice panicles that have been removed from the plant. Results show that the method estimates are at least as accurate as those obtained by manual measurements, being robust under a wide variety of imaging setups and conditions. Another major advantage presented by this approach is the ability of providing estimates for several panicles at once, either by processing several image files in a single batch, by processing images containing a large number of panicles, or both.*

***Abstract.** Este artigo apresenta um novo método baseado em técnicas de processamento digital de imagens tais como transformações de cor e morfologia matemática, bem como em conhecimento especialista, para fornecer estimativas para os comprimentos de panículas de arroz que foram removidas da planta. Os resultados mostram que as estimativas fornecidas pelo método são ao menos tão acuradas quanto aquelas obtidas manualmente, sendo este robusto a uma grande variedade de condições. Outra grande vantagem apresentada por esta abordagem é sua habilidade de fornecer estimativas para várias panículas de uma só vez, através do processamento de várias imagens em batelada, ou processando imagens contendo um grande número de panículas, ou ambos.*

1. Introduction

In agriculture, planning future actions is somewhat more difficult than in other sectors due to the high level of uncertainty that surrounds many of the parameters that support decision making. Thus, any strategy that is effectively capable of forecasting the behavior of at least some of those parameters are invaluable to the producers. One of the most important forecasts, in any culture, is the crop yield. Researchers around the globe are constantly working on the difficult task of creating models based on some collected parameters to make those predictions.

In the specific case of rice crops, there are several reports that the length of the panicles has a significant correlation with crop yield [Ganesan and Subramanian 2009], [Mahitkar et al. 2001], [Hittalmani et al. 2003], [Yoon et al. 2006], [Saif-ur-Raisheed et al. 2009], [Liu et al. 2011]. Also, there has been some work on the correlation between panicle length and the presence of diseases [Araújo et al. 2006]. In general, the length of the panicles is measured manually, after some selected samples are removed from the plants. The problem with this method is that, for the data to be statistically significant, a large number of samples have to be

measured, which can be tedious and tiresome. Moreover, the panicles tend to have a curvature, instead of being straight, adding more difficulty to the measurement task.

There have not been many attempts to automate this process. To the author's knowledge, the only proposal that comes close to this objective was proposed by [Duan et al. 2011]. In their work, they created a whole machine-vision-based facility to measure some yield-related traits in rice, however those do not include panicle length.

Therefore, the method proposed in this work is new, having the potential to benefit both researchers trying to create new yield forecasting models and producers in need for good decision support tools. The proposed method is mainly based on image processing techniques such as color transformations and mathematical morphology. It also includes extensive specialist knowledge to guarantee the accuracy of the estimates. As will be seen along the text, the method is capable of providing estimates at least as good as those manually obtained. Also, this approach has the ability of providing estimates for several panicles at once, either by processing several image files in a single batch, by processing images containing a large number of panicles, or both.

2. Material and Methods

2.1. Image Database

The database used in the development of the algorithm has 16 images, each containing between five and ten panicles and also a ruler to be used as reference in the conversion from pixels to centimeters. The images were captured in a laboratory after the samples were removed from the respective plants, using a DSLR (Digital Single-Lens Reflex) camera. They were stored in the RGB (Red-Green-Blue) format and quantized with 8 bits, and have dimensions of 4288 x 2848 pixels. The original background of the images is blue but, in order to test other setups, the backgrounds were also digitally made white and black, thus resulting in a total of 48 images (16 for each background color). Fig. 1 shows an example of a typical image. The length of the panicle is to be measured from the panicle base (often called neck) to the extremity of the topmost branch. The panicle base is marked with a black circle in Fig. 1a.

2.2. The Method

As stated before, the images were stored using the RGB color model. This format is appropriate for storage and visualization purposes, but it is usually not suitable for more sophisticated manipulations. After an extensive study considering the most used color models, the third channel (yellow) of the CMYK (cyan, magenta, yellow, and key) model was deemed the most suitable. After the color transformation, the pixel values are rescaled to span the entire range of values (0 to 255). The result is shown in Fig. 1b. As can be seen, in this channel the panicles are much brighter than their surroundings. As will be seen later, this is true even if the background is black or white.

The image shown in Fig. 1b is then binarized using a pixel value of 150 as threshold, that is, all pixels above this value are made equal to 1, and all others are made equal to zero. This operation separates the panicles from the background. In order to remove debris and spurious elements, objects that are smaller than 1% of the largest object in the image are eliminated, resulting in the image shown in Fig. 1c.

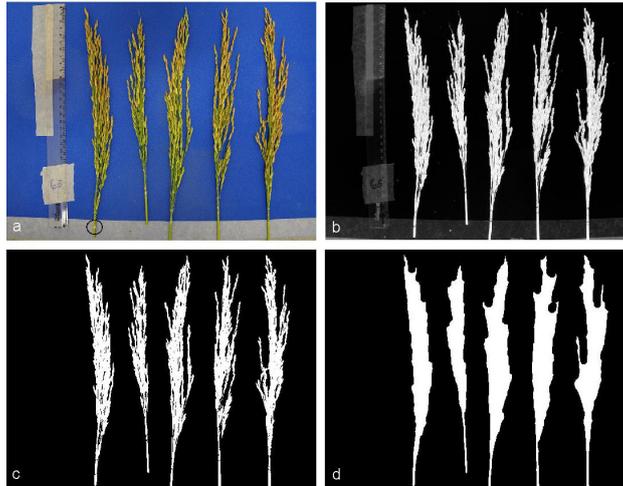


Figure 1. a) A typical image of rice panicles. b) Image represented in the yellow channel of the CMYK color model. c) Separation of the panicles from the background. d) Closed image.

Next, a closed image is obtained from the binarized one by applying a morphological closing, using as structuring element a disk whose radius is 1% of the size of the largest side of the image. Holes that may arise inside the objects are filled. This closed image, as shown in Fig. 1d, has as main objective to aggregate each panicle into a single continuous object. This is necessary because, in the thresholding process, some very thin parts of some branches may not be detected, which in practice may disaggregate a single panicle into multiple objects.

Each identified panicle will be treated separately from this point to the end of the algorithm. At this point, the algorithm must first identify the panicle base, which determines the actual bottom extremity of the panicle. By convention, the bottommost node beneath the panicle is considered its base. The nodes can be visually identified in Fig. 1a as light rings in the stem region.

First, the algorithm identifies the bottommost horizontal cross section of the panicle whose width is at least 25% of the maximum width of that panicle. The entire region below such point is considered as the potential region containing the base. Fig. 2a shows the binary mask of the first panicle of Fig. 1a, and Fig.2b shows the potential region.

Ideally, the potential region should include only the stem. However, in a few cases some regions containing the spikelets may be included. This can seriously harm the subsequent steps of the algorithm, so those regions must be removed. Those spurious regions almost always appear as a separate small object (see Fig. 2c). Using this observation, a region is purged if it shares at least 80% of the rows with any other object to its left or its right. For example, in the case of Fig. 2c, the left hand object spans from row 12 to row 100, and the right hand object spans from row 12 to row 25. In this case, the smaller object shares 100% of its rows with the larger one, thus being eliminated.

As can be seen in Fig. 1b, the panicle base appears darker than the rest of the panicle in the yellow channel of the SMYK color model. Sometimes, this is enough to cause a gap in the region of interest after the binarization. Thus, the presence of a gap

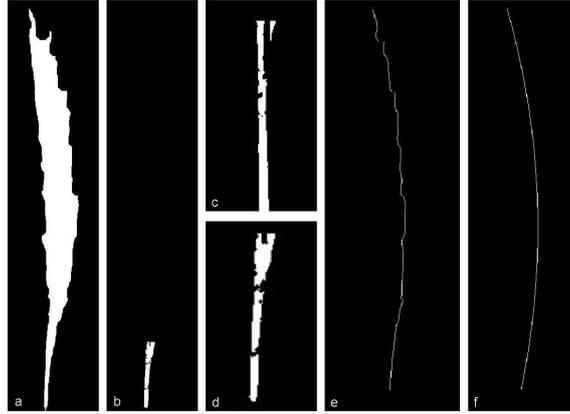


Figure 2. a) Binary mask of a panicle, generated from the closed image. b) Potential region for the location of the panicle base. c) Example of spurious region. d) Example of multiple gaps in the region potentially containing the panicle base. e) Path used to determine the main orientation and curvature of the panicle. f) Approximation of the path by a second order polynomial.

indicates the presence of a node at that point. If there is only one gap, such a node is taken as the panicle base; if there are multiple gaps, as in Fig. 2d, the bottommost one is taken as the position of the base; finally, if there are no gaps, the image is successively eroded until a gap appears. The position of the selected gap is taken as the starting point for the length measurement – the ending point being the topmost pixel of the closed image.

Having the starting and ending point for the measurement, the problem now is to determine how to measure the distance between them. The most straightforward choice would be to calculate the linear (Euclidean) distance. However, the panicles are not straight, they usually have a certain curvature that should be taken into account. Also, the path to be considered through the panicle should be as close to its central axis as possible. The solution adopted here was to identify the central white pixel in each row of the panicle’s binary mask. This creates a path with some discontinuities and irregularities (see Fig. 2e), making it unsuitable to be directly used for measurement. However, such a path gives a good visual sense of the general orientation and curvature of the panicle. In order to formalize this into a mathematical form, such a path is approximated by a second-order polynomial (Fig. 2f).

Finally, the length of the panicle is given by the length of the arc generated by the polynomial, which is given by the following integral:

$$length = \int_a^b \sqrt{1 + [p'(x)]^2} dx, \quad (1)$$

where a and b determine the extremities of the curve, $p(x)$ is the polynomial and $p'(x)$ is its first derivative.

3. Experimental Setup and Results

The method was trained and tuned using a single image containing five panicles. This image was not used in the validation tests.

All panicles present in the images were measured manually prior to the image capture. These manual length estimates were used as references for the results yielded by the program. It is important to highlight that the manual measurements are subject to errors due to the irregular shape and curvature of the panicles and also due to fatigue. Therefore, the manual annotations cannot be considered the ground-truth, but just a reference to the estimated lengths. It is important to take this into account when analyzing the results.

The overall mean squared error (MSE) between manual and automatic length estimates was around 0.1. This means that the average difference between manual and automatic estimates was around 3 millimeters, or about 1% of the average panicle lengths. Moderate errors of up to one centimeter occurred in those very few cases in which an incorrect node was identified as being the panicle base. Overall, considering that the manual estimates are not perfect, both approaches can be considered equally accurate.

Fig. 3 shows an example of the curves that the algorithm fits into each panicle. As can be seen, those curves are able to emulate the general curvature of the panicles and, apart from some small deviations, their extremities match well with the panicles ones.

An investigation was carried out to determine the influence of three factors over the performance of the method, as shown in the following.

- Background color: as commented before, the original blue background was digitally made white and black in order to investigate the influence of this factor on the results. The results were exactly the same, no matter the color of the background. This is because, after the color transformation, the original background tones become very different from the resulting color of the panicles. This is due to using the yellow channel of the CMYK color model, which, in practice, emphasizes yellow tones and diminishes all others. This means that a yellow background would cause the method to completely fail.

- Resolution: the tests were performed using 12-Megapixel images. In order to determine if lower resolutions would result in worse results, the images were downsampled to 5, 2, 1 and 0.5 Megapixels. Again, there was no statistical difference across the resolutions. In practice, it was observed that if the panicle base can be clearly identified by a human, the algorithm will also be able to do so and, since this is arguably the most important step of the method, it guarantees that the length estimates will be accurate.

- Number of panicles in a single image: in this case, the same observations hold, that is, no matter how many panicles are in the image, if a human can identify the panicle base, the algorithm will work properly. However, it is important that the smallest gap between two neighbor panicles be at least 1 cm, in order to avoid interference.

Finally, it is important to remark that no comparison with other methods is presented because there is no other equivalent proposal in the literature.

4. Conclusion

This paper presented an automatic method to measure rice panicle lengths using digital image processing techniques. Despite its simplicity, it was shown that the proposed algorithm is capable of providing estimates at least as accurate as those manually obtained. It was also shown that the method is robust to factors like resolution of the image, color of the background and number of panicles in a single image. Future work will be dedicated to improve the process of picking the right node as the panicle base.



Figure 3. Example of curves fitting the panicle shapes.

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