Rice Spikelet Yield Determination Using Image Processing

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***Abstract*—There is a lot of Philippines rice varieties that need profiling according to Philippine Rice Research Institute (IRRI)[1]. While current methodology involves manual process and normally takes more than a week to complete, improving and developing a new variety is thus slower due to this aspect. This study proposes an automatic technique to perform profiling of rice spikelets using camera system and image processing technology. The system automatically counts and separates filled and unfilled rice spikelets using a camera, analyze the captured spikelet image by image processing, view and control the resulting data through a graphical user interface specifically designed to cater user's needs. Different varieties of rice samples are tested and validated with the current methodology. Result from 30 samples for each rice variety showed device accuracy of more than 95% was obtained.**

***Keywords*—Rice spikelet, rice profiling, grain counting, GUI, image processing**

I.INTRODUCTION

Philippines is the 8th biggest rice supplier in the world [1]. The government, through its agency International Rice Research Institute (IRRI) aims to improve the quality of rice by enhancing the old varieties and developing new varieties to adapt to different climates in the country.

According to Dr. Norvie L. Manigbas, a PhilRice scientist, there are a lot of rice varieties in the Philippines still needs profiling. It normally takes more than a week to complete the process of profiling the different rice varieties thus acquiring data takes a lot of time and labor. In a rice field, they will not pick the outermost plant because of what they call this border effect. Border effect is defined as the difference between the behaviors of the plants adjacent to the border compared with that in the center field. It is the basis for all crop spacing recommendations presently in practice worldwide.

One of the operations performed in the IRRI is rice breeding. After altering the genetic model of rice, IRRI will plant and harvest the certain rice variety for profiling purposes. In their existing process, rice profiling is done by harvesting ten (10) plant samples of every variety of rice plant then gather the data needed for profiling. Measuring the rice plant height is done with a meter stick. Hand threshing is used to remove the grains from the panicle. Then, grains are manually separated, classified as either filled or unfilled and will be fed to the counting machine. According to IRRI, the whole process of rice profiling can for last weeks due to this time-consuming procedure.

Hence, to provide a convenient and faster result of profiling, this study is developed. Specifically, this study aims to automatically count and profile rice spikelet using image processing technique. It also intends to provide a faster way of rice plant profiling, and automatically compute for the yield of a certain rice variety. However, the size scales of the spikelet/grains and panicle branches are significantly different, and therefore, it is difficult to simultaneously extract both [6].

A. Rice plant

The rice plant with scientific name Oryza Sativa, from the grass family Gramineae, has a plenty of variety. Its height can range from 0.4 to more than 5 m. The rice plant needs a significant amount of water but is not considered a water plant. The rice plant normally takes 3 to 6 months to fully grow (germination to maturity) but depends on the variety and conditions under which it is grown. During this period, rice plant basically undergoes two distinct sequential growth stages: vegetative and reproductive, which is split into preheading and postheading or the ripening period. The potential yield of the drop is determined during the preheading phase while the amount of starch inside the spikelets or the ultimate yield is determined during postheading. Depending on the variety, a 120-day type would take about 60, 30 and 30 days in the vegetative, reproductive and ripening stages, respectively. (books.irri.org).

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The rice plant is composed of vegetative organs (roots, stems, leaves, sheath, and ligule) and the reproductive organs or the panicles, flowers and grains. The rice seed consists of an outer part, which is called husk, and grain, which is the edible part. During planting, the whole grain is planted without removing its husk. Under the husk is the rice grain covered with a layer of bran. When rice has its bran intact, it is called “brown” rice, otherwise it is known as “white” rice.

For every rice variety, its grain length, width and thickness are also varied, typically weighing 10-45 milligrams at 0% moisture. Husk weighs approximately 20% of total grain weight. For proper storage of rice plant, it must be kept in paddy form rather than milled rice as the husk provides some protection against insects (ricepedia.org).

Panicles or flowers of rice is located at the end of each tiller. Rice is mostly self-pollinating, or they can fertilize itself with its own pollen, by wind alone. The development of grain production starts as soon as the rice has been self-fertilized and the panicles grow substantially with maturing rice grains. Figure 1 shows the parts of a rice panicle and tiller. [5]

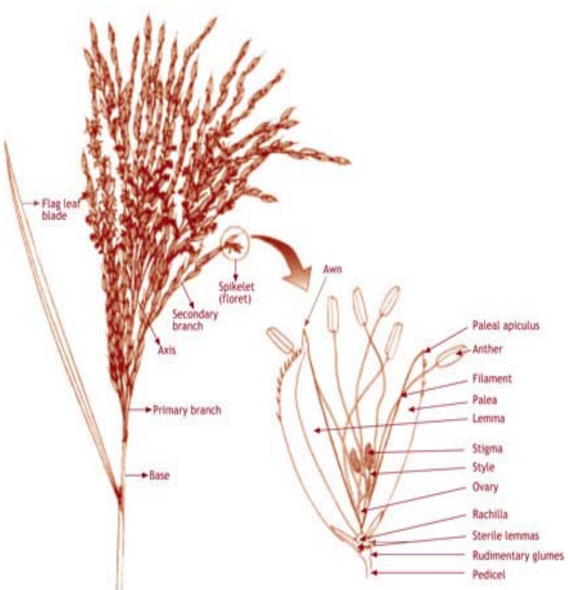

Fig. 1 Parts of a Rice Panicle and Tiller [9]

B. Rice Plot Yield Components

Yield of rice is usually recounted as rough rice (paddy) at 14% moisture content, with the exception of Japan and Korea, where yield is expressed in terms of brown rice or polished rice. A conversion factor of 1.25 is usually used when brown-rice yield is converted to rough-rice yield (books.irri.org).

There is different mathematical approach used in computing the rice yield. The formula that utilizes the parameter number of spikelets present in each rice panicle is considered in this study. The grain yield per plot is computed using this formula:

$$Grain\ Yield\ \left(\frac{t}{ha}\right) = panicle\ \frac{number}{m^2}\ x\ spikelet\ \frac{number}{panicle}$$

$$x\ \%filled\ spikelets\ x\ 1000grain\ wt.(g)\ x\ 10^{-5} \qquad (1)$$

TABLE I
Rice Plot Yield During Wet and Dry Season

Component	Wet Season	Dry Season
Panicle number per m2	250	375
Spikelet number per panicle	100	100
Total number of spikelets per m^s	25 000	37 500
Filled spikelets (%)	85	85
100 grain wt. (g)	29	29
Expected Yield (t/ha)	6.16	9.24

II. METHODOLOGY

As Matsushima (1970) indicated, each yield component is determined at a particular stage in the plant's life. The number of panicles per square meter depends on the tillering performance for the transplanting rice cultivation, and seeding rate for the direct seeding system. The number of spikelets per panicle is formed in the course of the reproductive growth stage. While filled spikelets percentage is found before, at, and after heading. The growth of the spikelets could be hindered during ripening process brought about by unfavorable weather conditions which results unfilled spikelets.

The methodology used for this study is illustrated in the block diagram shown in Figure 2. The rice spikelets are placed on the platform with shaker and camera module. The data in the form of an image is saved and proceeded for different processing steps and computations through the software application. Then, result is viewed and saved in the database for future reference.

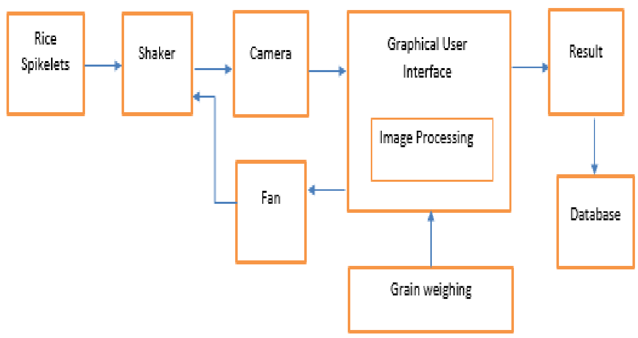

Fig. 2 Block Diagram of the Study

During testing, rice spikelet is placed on the surface of the chamber. The shaker is utilized to avoid overlapping of the spikelet. Using light emitting diodes (LED) device as a light source, the camera captures the image and processed, counted and saved as ‘Total Number of Spikelet’. After image capturing, winnowing or the separation of filled from unfilled spikelet is done using the fan installed near the surface of the chamber. On the other side of the chamber is a container where unfilled rice spikelet is separated by a blower or fan. Shown here are ten (10) sets of tests done for every rice variety.

A. *Hardware*

The prototype shown in Figure 3 is an enclosed chamber with an acrylic platform where the rice spikelet is placed. Installed inside it is a 1080-pixel high definition web camera positioned to capture images of the rice spikelet in a defined height, as seen in the figure 4. Fan and shaker help separate the grains and the unfilled rice spikelet goes to the catching unit.

Fig. 3 Chamber prototype

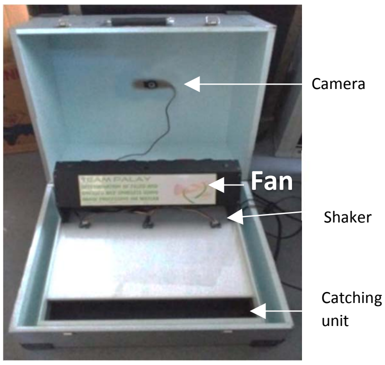

Fig. 4 Inside photo of the Chamber

To prevent the rice spikelet from overlapping, a shaker is placed on the surface so that less error will be obtained when the image is to be processed. A digital mini weighing scale with was used to measure filled rice spikelet considering the parameter ‘1000-Grain Weight’ was used in rice profiling. A 12VDC 800RPM fan was used for the separation of filled from unfilled spikelet. A12VDC LED module was placed underneath the surface for proper lighting so that no shadow will be formed during image capturing.

B. *Software*

Software design of the system is composed of a Graphical User Interface (GUI) as shown in Figure 5 wherein the camera can be controlled as well as display results of each test.

Using C# language, the GUI was created in Microsoft Visual Studio. Count function which was used for the counting of the number of rice spikelet from the image captured was generated using MATLAB Shared Library and was incorporated into the GUI. The results obtained from each testing were saved to a database using SQL (Search Query Language) Client.

C. *Graphical User Interface.*

The graphical user interface shown in Figure 5, contains the process of the whole system, from control of the camera to generation of results. Using ‘test’, the GUI will automatically count the number of spikelets in the image. Inputting different parameters such as ‘Panicle per square Meter’, ‘Spikelet per Panicle’ and ‘Filled Grain Weight’, the GUI will automatically compute for the unfilled rice spikelets, percent filled, 100grain weight and the Yield.

Fig. 5 Graphical User Interface

D. *Image Processing*

After acquisition of the captured image, the RGB image will be converted to grayscale so that the processing will be easier and faster since only different shades of gray pixels will be analyzed.

The transformation of RGB to grayscale can be obtained using this formula:

$$I = \omega R \ X \ R + \omega G \ X \ G + \omega B \ X \ B \qquad (2)$$

Where $\omega R = 0.30$, $\omega G = 0.59$ and $\omega B = 0.11$ are the weight values of components *R, G* and *B,* respectively [2].

Figure 6 shows the original image and Figure 7 indicates the transformed grayscale image [7].

Fig. 6 Original Image

Fig. 7 Transformed Grayscale Image

The next step is image binarization wherein the grayscale image is transformed to binary pixels 1 and 0 or black and white. This method is used to distinguish the background from the objects evidently. The method thresholding is used for the conversion. Figure 8 displays the binary image formed.

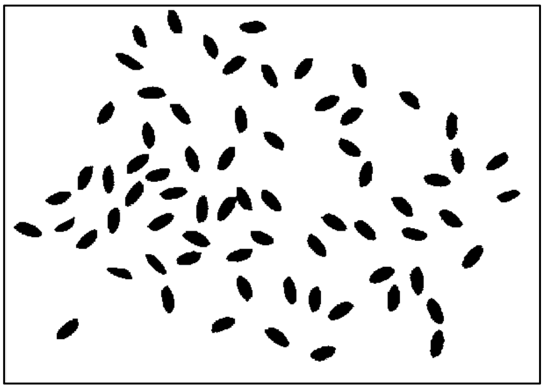

Fig. 8 Binary Image

Image segmentation will be then employed so that edges of every object on the image will become sharp hence detecting the objects will be simpler. For this process, watershed technique was used to determine if two spikelets stick together in the image. This is done by finding the watershed lines and the catchment basin of each object in the image [3]. Figure 9 shows a watershed mask image produced.

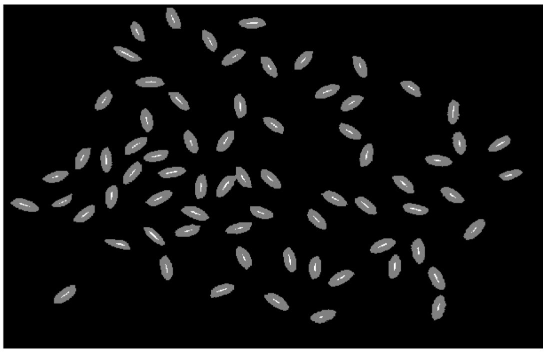

Fig.9 Masked Image

When watershed is done, the pixels are concentrated in the center of the objects in the image, making it easier to identify the background of the object; grain counting realization of the image happens using MatLab Count function [4].

A. Rice Yield

Yield parameter measures the effectiveness of a given variety. There are two methods on how to measure the yield of a rice plant, first is to measure the total dry weight and dry grain yield and get the ratio of the two while the other one is calculating by breaking the yield into its components. The formula for the yield using yield component is

$$Grain\ Yield\ \left(\frac{t}{ha}\right) = spikelet\,\frac{number}{m2}$$

$$x\ \%filled\ spikelets\ x\ 1000grain\ wt.(g)\ x\ 10^{-5} \quad (2)$$

where % filled spikelets can be obtained by

$$\%filled = \frac{filled\ spikelets}{total\ no.of\ spikelets}\ x\ 100\%\ \text{Eq.} \quad (3)$$

Rice yield is usually reported as rough rice at 14% moisture content [5].

B. Plot yield and Its Parameters

The result would include parameters such as the total number of rice spikelets, number of filled and unfilled rice spikelets, 1000-grain weight, panicle per square meter, spikelets per panicle, the resulting percent filled spikelets and the yield.

III. Discussion of Results

Samples were threshed manually from panicles of each variety. Three rice varieties were tested using the proposed device.

In the first set of experiment and testing of Jinmibyeo variety, the data acquired though manual counting is compared with the average result values. Table II shows the total count of samples and the resulting counts of filled and unfilled spikelets using the device. An average of 172.2 with an accuracy of 97.34% is acquired for the Total Count. While averages of 142.7 and 29.5 were computed for Filled and Unfilled spikelet, respectively, with corresponding percentages of accuracy of 97.34% and 98.28%. Also, Figure 10 shows a comparison of the actual data using manual process and average data gathered for the first ten of 30 tests for rice variety 'Jinmibyeo'

TABLE II
Testing using Jinmibyeo variety

Test No.	Total Count	Filled	Unfilled
1	172	147	25
2	171	144	27
3	168	140	28
4	173	145	28
5	170	144	26
6	182	139	43
7	168	145	23
8	173	141	32
9	176	137	39
10	169	145	24
Average	172.2	142.7	29.5
Actual	168	139	29
Accuracy	97.5%	97.34%	98.28%

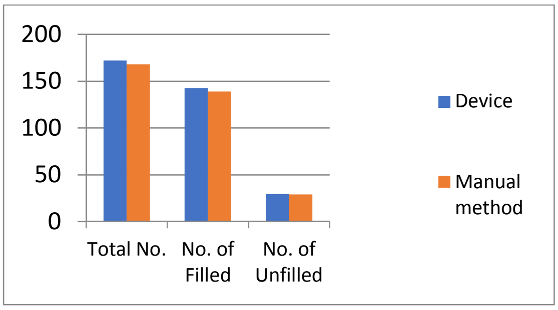

Fig. 10 Comparison between Actual and Tested Data of Jinmibyeo

The rice variety called 'Dasanbyeo' was tested and showed high percent of accuracy of result as shown in Table III and Figure 11. Table III shows the total count of samples and the resulting counts of filled and unfilled spikelets using the device. An average of 150.8 is acquired for the total count and 119 and 31 were the average readings for filled and unfilled spikelets, respectively. Accuracy of 99.47% is computed total count while 100% and 97.42% are gained for the accuracy for filled and unfilled spikelet values. Figure 11 shows a bar chart of the first ten tests for rice variety 'Dasanbyeo' comparing the actual data using manual process to the average data gathered.

TABLE III

Testing Using Dasanbyeo variety

Test No.	Total No.	Filled	Unfilled
1	148	117	31
2	149	118	31
3	150	110	40
4	149	119	30
5	155	125	30
6	149	121	28
7	150	122	28
8	149	119	30
9	153	121	32
10	156	118	38
Average	150.8	119	31.8
Actual	150	119	31
Accuracy	99.47%	100%	97.42%

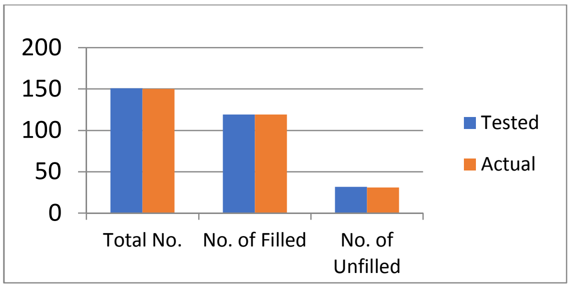

Fig. 11 Comparison between Actual and Tested Data of Dasanbyeo

For the second set of testing, every test was compared to the actual data and the percent accuracy was computed for each test. Tables IV to VI show the first ten tests of the 'NSICRC-17' rice variety. Average accuracy for these set of tests is calculated 97.4%.

TABLE IV
Testing for Total No. of Spikelets of NSICRC-17

Test No.	Total No. of Spikelets		
	Tested	Actual	% Accuracy
1	112	110	98.18
2	91	86	94.19
3	148	146	98.63
4	109	106	97.17
5	110	112	98.22
6	85	83	97.59
7	99	97	97.94
8	161	158	98.10
9	102	94	91.49
10	89	86	96.51
Total	1106	1078	97.40

TABLE V

Testing for No. of Filled Spikelets of NSICRC-17

Test No.	No. of Filled Spikelets		
	Tested	Actual	% Accuracy
1	103	100	97.00
2	86	79	91.14
3	137	132	96.21
4	102	97	94.85
5	105	101	96.04
6	78	75	96.00
7	93	91	97.80
8	143	142	99.30
9	85	87	97.70
10	82	80	97.50
Total	1014	984	96.95

TABLE VI
Testing for No. of Unfilled Spikelets of NSICRC-17

Test No.	No. of Unfilled Spikelets		
	Tested	Actual	%Accuracy
1	9	10	90.00
2	5	7	71.43
3	11	14	78.57
4	7	9	77.78
5	5	11	45.46
6	7	8	87.50
7	6	6	100.00
8	18	16	87.50
9	17	7	-42.86
10	7	6	83.33
Total	92	94	97.87

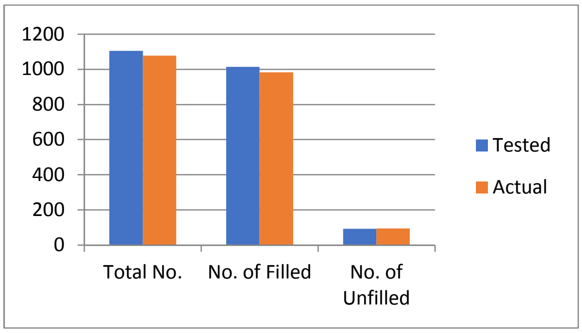

Fig. 12 Comparison between Actual and Tested Data of NSICRC-17

Furthermore, it is observed from the values obtained by performing the second set of testing showed a high accuracy measurement for variety NSICRC-17. An accuracy of 97.4% for Total Number of Spikelet as seen in Table IV. While an accuracy of 96.95% and 97.87% are amassed for Filled and Unfilled Rice Spikelet, respectively.

For the overall results, percent error of each testing ranges from 0 to 5%. meeting the standard accuracy followed by the user for the rice profiling. Also, the time consumed while testing each sample was observed to be between 30 seconds to 1 minute based on a time study performed, hence making the rice profiling faster and easier.

Results from testing the number of unfilled spikelets has a wide range of variation from 0% to more than 100% mainly due to the fixed speed of blower in the winnowing process. This has affected the result for the said parameter primarily because of the size and weight of a grain of a certain rice variety. However, after selecting the appropriate wind speed of the blower, a more accurate response was observed.

IV. Conclusions

The development of the image-based system that provides yield and rice profiling for three varieties was successfully implemented using image processing and simulation employed in MatLab . Also, it was able to automatically separate and count the number of filled and unfilled spikelet with the help of fan and vibration motor. The target accuracy which is 95% or greater was successfully attained for each rice variety. Additionally, the plot yield was calculated through the parameters such as the number of filled and unfilled rice spikelets. The other parameters needed for the plot yield can be encoded and manually entered in a mobile application designed for this device.

Result from testing Dasanbyeo showed 0.53% error for the Total Count, 0% error for Filled and 2.58% error for the Unfilled Rice Spikelet. This is mainly due to the size and shape of spikelets, making the image acquired easier to interpret.

Moreover, the researchers would like to impart two suggestions for the improvement of the project. First is the addition of other parameters needed for the plot yield computation; second, the modification of the testing surface to be wider to accommodate the whole panicle for testing and lastly to target an accuracy of 100% for each rice variety, especially on the number of unfilled spikelets.

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