An Economical Design of Automatic Rice Grading using Image Processing

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Abstract*: Product quality inspection is a crucial step in the production line of rice industries. To maintain the quality and enhance the inspection methodology, the challenge is to scrutinize rice grain individually over entire batch for escalating the yield. The conventional method used in rice industries is to examine the quality of rice grains manually. The decisions made by human quality control inspectors may be affected by external influences like fatigue, exhaustion or stress which causes non uniformity in evaluation procedure and generate the high probability of errors. The major drawback of the manual inspection comprises high labor content and expenditures. This research paper provides a cost effective design solution to overcome the described limitations by developing a system which helps in sorting rice and eliminate the manual examination. For attaining the automatic grading of rice, the image processing technique is applied which help to sort defected rice grain from the entire batch of rice grains. The system has been developed on MATLAB which helps in the inspection process and its graphical user interface provides information of rice grains in three different quality based categories which sorted on the basis of size and colors. To identify the defected grains, the multilevel threshold method of image processing has been used. The proposed design also helps to determine the quantity of defected rice grains by evaluating the quantity of discolored grains and to identify the size of the rice grain, the geometrical features extracted for each individual rice grain are used to estimate the length.

***Index Terms*: Rice grading; Image processing; MATLAB technique; Multilevel threshold.**

I. INTRODUCTION

In all around the world, rice is the most popular diet among humans and widely used in different cuisines. According to the statistical report of 2017, many countries including Pakistan, India, United States, Thailand, and some others exported the highest dollar value rate of rice. In the world, Pakistan is the fourth largest cultivator of rice and produces approximately 6 to 7 million tons of rice [1]. According to REAP (Rice Exporters Association of Pakistan), in year 2015 to 2017, Pakistan exported around 4,262,216 metric tons' rice all over the world and earned $1.860 billion dollars. Moreover, the export of rice in

Pakistan is increased around 27% in the month of February 2018. Also, in gross domestic product of Pakistan (GDP), the export of rice contributes around 1.3 to1.6 percent [2]. Because of this significant effect on economy, the compromise on the quality of rice is unavoidable for the progressive export business.

Quality inspection is an important part of the production line in food industries. Therefore, it is essential to optimize the traditional methodology of quality control and involve the modern technology in the field of inspection. To evaluate the quality of rice grains, the conventional method is adopted by different rice industries is through manual scrutiny which is done under the supervision of quality control department but this conventional method has major limitations of process time and accuracy because the it is nearly impossible for a human to evaluate individual rice grain from the entire batch of rice grains therefore, in manual examination the accuracy of detecting individual rice is compromised which decreases the yield of rice industries. For an effective quality inspection of rice grain in terms of process time and accuracy, it is required to obsolete manual method of inspection and introduce the modern automation technique in the inspection process and involves a system which not only evaluates the quality of the grains but also grade it into different qualities and the quality of rice can be improved by identifying and differentiating the defected rice grain from the entire batch of grain of rice [3], [4]. For the automatic identification, the image processing technique is the most popular technique to detect the defected rice grains and to achieve this MATLAB tool is commonly used because of its easy and comprehensible environment.

There are several methods of image processing based on the classification of the shape and color, that can be used to detect the defected rice grain such as histogram method, edge detection, RGB model and some other models [5], [6]. The RGB (Red, Green and Blue) color model is normally used in the field where image detection is required on the basis of color [7]. The image is formed by the combination of three different color channels consist of three natural colors named RGB which include in the most common factor of color space. The RGB model is also termed as additive model as its spectrum varied after mixing all three color with different combinations. The RGB model generates 16,777,216

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different colors spectrum combination with 256 values of intensity where at zero intensity level RGB model represent the dark shades of colors and the highest levels of intensity represents the light shades of colors [8]. The RGB model has the limitation of nonlinearity. Another popular technique for identifying the boundaries of any object in image processing is the edge detection technique. There are several methods for detecting the edge of any objects such as gradient differential filters, Prewitt and Sobel kernels. The main challenges to detect edge of any object are the strength of the edge or the gradient of any object, the noise present in image which causes to interfere the boundaries of object and smooth edges where gradient varied of over finite area [8]. Other technique includes the histogram modeling where, a means values of the dynamic range of an image provided to modify image and its histogram scattering imitates to a given shape [8]. Histogram demonstrates the information in terms of frequencies. Like other graphs, it has two axes which includes, X axis contains the event and Y axis consists of the frequency. Histogram values shows in the form of bars. An image histogram also shows the frequency. But, it shows the frequency of pixels and intensity values. In image histogram grey level intensities occurs, because, for any operation, image must be in gray scale format. That is why, grey level intensities occur in image histogram. On x axis, grey level intensities occur, while on y axis the frequencies of intensity in grey level occur. For example, take a histogram of any image. Large number of bars shows in any area shows the darker part of an image. It means darker the image, more bars in histogram.

In this research paper, the identification of defected rice grain is done economically on the basis of shape and color of a rice grain and analysis of the quantity is performed accordingly to the amount of defected rice grains present in a batch and all process is implemented through image processing technique using MATLAB environment. This would only require webcam for image acquisition and any processor to handle MATLAB environment and process real time operation. The system also consists of a mechanical structure along with a conveyor belt system coupled with a motor for the movement and grading of the rice according to the quality grading standards. The system does not require any human involvement in identifying the defected rice grain, therefore, the system eliminates the labor interference in the inspection process and overcome the issues of manual inspection with increase efficiency and production rate. The proposed design consisting of a mechanical structure along with a conveyor belt coupled with a motor and a webcam which cost around 28 to 30 USD for evaluating the quality of the grains, the price variation is depending on the pixel quality of different cameras available in market. An economical prototype is designed to perform test for the grading of rice which sort out three different qualities of rice and differentiate them according to the predefined threshold quality of defected rice grain. The cost of prototype design is around 370 USD to test the proposed idea. The main concept is to propose a design which is an efficient, cost effective and helps to minimize the labor cost because in existing grading methodology, this process was done manually.

II. LITERATURE REVIEW

According to agricultural survey report of Pakistan, the rice industry has given more profit in terms of export business all over the world. For this reason, the industries expanded their cultivation area approximately 174 thousand hectares in the time span of 2017 to 2018 which raised the production approximately 593 thousand tons in only one year [9]. To maintain the progress and positive growth of the export rice industry of Pakistan, there is a need to fill the gap in different industrial procedures by replacing the manual mechanism to the automatic system which would help in eliminating human errors and delivering perfection with respect of quality. The automation of packaging and grading of the rice makes the life much easier, for this purpose, image processing plays a vital role to automated the grading mechanism of the rice and also used to check the quality of rice. According to some researchers, there are many different parameters to determine the rice grain quality such as size, shape, color, texture, external defects of the grain and to detect the defined parameter, there are several image processing techniques have been used to make rice grading more efficient such as the classification on the basis of RGB, greyscale and intensity values acquired from the image [7]. Other researches includes the investigation process of internal fragmentation of rice kernel [10]. In recent years, there are many improvements made in the image processing field and many methods are used in the grading processes such as machine vision technology and neural networks [11]. Machine vision is a technology in which the information can automatically extracted from digital images by using cameras. Machine vision technology widely used in manufacturing process in the industries. It has many advantages. It is faster, more consistent and also use for longer periods of time. Machine vision has four basic functions: measurement, counting, location and decoding. Some of the examples of machine vision technology is from industrial manufacturing process are bar code reading, specify missing caps in manufacturing process, inserting a batch on cans, check location of bottles. In neural network is a method on the way biological nervous system works to simulate the learning processing which required specialize hardware and algorithm to process all the given information [12]. Some research scholars suggested that by using method named support-vector-machine (SVM) considered to provide maximum sorting accuracies, as a design sorter and set of controlled and linear sorter [13]. Another technique is image warping approach to find the unknown grain varieties [14] and also by using black background technique, effectiveness of image processing can be increase. When the morphological features are combined with the color, the accuracy of the result can be improved drastically. Some of the technology used transform training pattern vectors to train the kernel along with support vector machine and then tested by using specific methods. In these techniques

images can either be static image or in the form of a video frames can be used for real time classification. However, these methods for evaluating the quality of grains are expensive and time consuming. Firstly, the sample rice grading has been categorized into good, medium, not good, worst category or it can be named as A, B, C and D. These sample can be used to determine the grading for the test sample.

For process of automatic classification of the rice grains must be ease to use and robust. The system must be capable of grading the heaped or scattered grains on surface which makes the system robust and easy to use. In scattered rice separating individual rice is a challenging task as each rice grain in touch with the other leaving a very faint boundary, which cannot be detect easily. Also these grains sample cannot be reject as the number grain are limited in the sample. Researcher Hobson et al [15] used unsupervised clustering method for the classification using various features. Rajalingappaa et al [16] utilized morphological operations to identify touching components. For the separation of touching grains, Fourier analysis [17] and the method on convexity of boundary of two touching grains is used but in this method there is the limitation of amount of grains. Rice grain overlapping each other has a serious disadvantage, boundaries are not clearly visible and noise appears more prominent than the boundaries. In some areas of the world chemical methods are also used for the classification of rice grain. But these chemical methods are destruct the used sample and usually takes a lot of time. L.A.I.Pabamalie, H.L.Premaratne [18] focus on developing a better way to identify the quality of grains with the help of artificial neural networks and image processing. In artificial neural network (ANN) helps in image processing by building, recognizing, grading and reconstructing the image. An image can be represented in different forms. An image can be represented in a matrix form. When an image is converted into a matrix form, it contains the matrix elements. These matrix elements show the color information of pixels. Then these matrices given as an inputs to neural networks for process. Also, neural networks are used to identify the image. It identifies the image by giving the input in the form of an array (which contains RGB color). This research has done to identify the identify the relevant duality of the sample and was based on the color of the grain. Harish S Gujjar, Dr. M. Siddappa [19] used and image wrapping method for the identification.

III. METHODOLOGY

Image processing has numerous applications in many technical fields, but still its application in quality inspection in rice industries is restricted. In this design, image processing technique is utilized for the quality inspection of rice grains, which helps the system in evaluating the number of defected rice grains. There are several processes which are available in rice industries, out of which most of these are mechanical processes, as it can separate the variation is size but are not capable to grade rice on the basis of color defect which causes major issues in the final product. Mechanical processes, such as length grader and manual inspection, have been used in rice industries with less cost and is capable to grade rice on the basis of color defects resolving the major issues of rice industries. The project would greatly contribute more efficiently in the rice industry and take less time as compared to manual inspection and in turn, it will reduce labor cost, which ultimately results in the betterment of rice industry. To analyze and differentiate the quality and quantity of defected rice grain, a prototype is designed, which includes a mechanical structure for sorting the good and defected sample of rice grain from a batch.

A. Prototype Design

To acquire goal, a prototype is design which includes IR sensors to detect the presence of batch consist of rice grain, camera which capture the image of batch present in conveyor for further processing in MATLAB to identify the defected sample, Controller is used for decision making with respect to the threshold values of defected samples analyze through image processing and control motor for sorting into three different qualities of rice by means of different set threshold values. Figure.1, represents the block diagram of prototype design for testing.

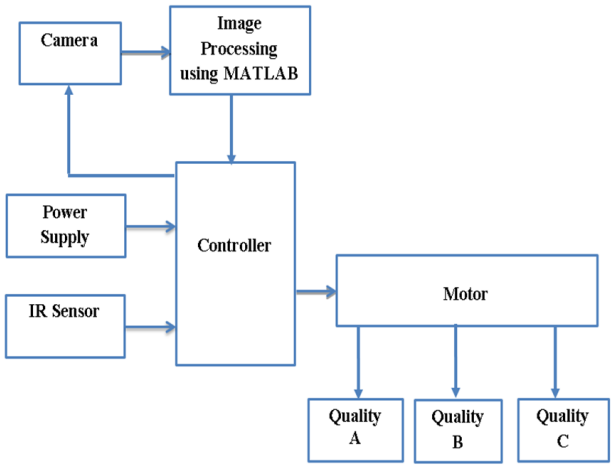

Fig. 1. Block diagram of proposed prototype for image processing based rice-grain grading system

B. Mechanical Structure

In order to control the movement of the rice grains over the conveyor system and grade them according to the 4 different grading standards, a mechanical structure has to be developed which is capable of controlling the motion of the rice grains for the examination of the rice grains using a webcam and an image processing algorithm on MATLAB. Once the processing is completed then the mechanical structure should proceed with the quality grading according to the inspection results produced by an algorithm on MATLAB. To determine the size and color defect, variety of rice samples were used which includes long grains, short grains, and some discolored rice grains. The images of rice grains were acquired on a white background tray with a webcam of 16 mega pixel resolution. For testing on small scale, the grains were scattered on the tray manually to avoid overlapping. It can set on vibrating conveyor for the large-scale purposes, but the

cost will slightly increase as vibration will be produced by introducing additional motors. In figure 2, the mechanical structure of prototype is shown, which includes conveyor where batch of rice grain is placed and IR sensors are installed in the chamber to determine accurate position of batch containing rice grain sample, which helps the camera to capture perfect image of the grain. The IR sensor, which is interfaced with the Arduino detects a box, stops the conveyor belt immediately. When the IR sensor detects a box, it sends a high signal to the Arduino, which detects the operation in the MATLAB program and stops the conveyor. After the detection of box, the next step is to perform the acquisition of the real time image of the box which contains rice grains through webcam which is installed on the top of the chamber to process the image on the laptop in real-time scenario. The image captured is transmitted to the MATLAB software, where the feature extraction of image is done and all the other decision making steps, such as quantity analysis of defected & non-defected rice and calculating the ratio of defected rice, are performed. When the conveyor is started, the box moves forward again, in the meantime the decision is made on basis of the ratio of the defected grains present in the box. Now, the segregation or grading of the box is done by servo motor which works on the reference position. The motor is connected to the structure, which is controlled by Arduino for sorting mechanism.

Fig. 2. Prototype mechanical system

C. **Image Processing**

Image processing is one of the necessary steps used to enhance the quality of the acquired image to get useful information from it. Various operations are performed to remove the imperfections, such as repetitive noise, improper focus, and non-uniform lighting. There are many platforms which can be used for image processing, such as MATLAB, Python, openCv, but in the proposed design, MATLAB is used because it is easy to use and there is no need to add any external libraries in MATLAB for performing digital image processing. Proposed system uses median filters for smoothing and removing the additive noise from the image. Figure. 3 describes the various steps performed by the system for quality inspection and grading of the rice grains.

Fig. 3. Procedure for analyzing defected rice grain.

1) IMAGE ACQUISITION

For analyzing the defected rice grain, an image acquisition is the necessary step to obtain images which are in the form a three dimensional array. The conveyor mechanism runs through the motor until the detection of rice grains is detected. Once the conveyor mechanism stops due to the detection of rice grains then, the Images of the rice grains were acquired through the webcam mounted over the mechanical structure and stored in the JPEG format into the computer. For performing different operation on image, MATLAB platform is widely used because of the availability of extended range of tools and features for different applications. By using the snapshot function in MATLAB, an image is captured and then stored in the variables for performing operations. The images acquired are in the form of RGB which contains color intensity value between 0 and 255. The dataset was organized such that it forms four different categories for four different defects as shown in Figure 4. First category is the defected rice grain, in which rice is completely black or more than half of the area of rice grain is black in color. The second category is discolored rice grain, in which color of rice grain is brown or shades of the brown. The third and fourth category includes the short and long grain of rice, in which grading will be done on the basis of length of the rice grain.

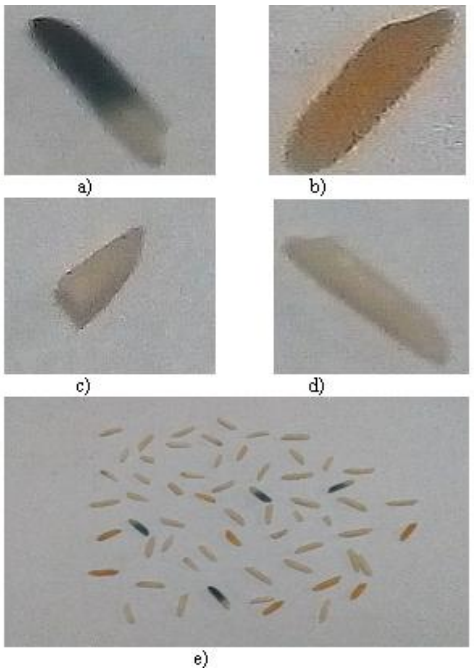

Fig. 4. Testing samples of Rice Grain, a) Defected Rice Grain, b) Discolored Rice Grain, c) Short Grain, d) Long Grain, and e) Batch of Rice sample

2) Converting RGB to Gray Scale

After the image acquisition, the image will have to convert into grey scale, which helps to minimize the complexity and reduce the processing time by converting three dimensional array into two dimensional. This process can easily be done by using MATLAB built in function of rgb2gray which contain intensity range of pixels between 0 and 255.After the conversion, intensity of pixel varied according to the different colors of grains.

a) Binary Image

The grey scale image is, then, converted into binary image, which contains pixel intensity of 0 and 1. The binary image is formed by using im2bw function with a multilevel threshold value that subtracts the background of the image from the foreground pixels. The binary image contains noise, which can be removed by using some morphological operations on the binary image.

b) Image Filtering

Images acquired cannot be directly used due to the internal and external noise, which causes poor contrast and variation in the intensity values. The system uses imadjust function for contrast adjustment. Various types of filtering techniques can be employed for smoothing of the image. The system uses median filter by using medfilt2 function to remove the noise and preserve the edge information from the image.

c) Quantity Analysis of Rice Grains

It is essential to estimate the quantity of the rice grains in the binary image to extract the geometrical and color feature of each rice grains. The quantity analysis of rice grains of proposed systems is done by using bwconncomp function, which returns the number of associated components in terms of binary image.

d) Feature Extraction

After calculating the number of linked components, the system extracts the geometrical and color features of each rice grain using built-in function regionprops from the binary image. Features included area, major axis length, minor axis length, perimeter, eccentricity, aspect ratio, maximum intensity, mean intensity, and minimum intensity.

e) Rice Grading

The grading of the rice is done into three different categories on the basis of size and color. The system extracts the short grain, long grain, and defected rice grain using bwpropfilt function which helps in extracting different quality of the rice grains by using the extracted features.

IV. RESULTS

The recognition result of the proposed algorithm is presented in the tabular form. The Table 1 represents the final outcome of the proposed design. In following table, it includes four categories of data set of the rice grain such as DF represents defected rice grain, DC represents discolored rice grain, SG represents short grain, and LG represents Long Grain. To set benchmark for testing proposed system, all four categories are inserted on purpose, manually, with total rice grain 60 in quantity. For manual inspection, the average data is collected by 20 persons who are selected randomly. All the comparisons were done upon these set benchmark values (known standard), these comparison yields the relative error in the recognition of rice grain manually and by automatic inspection.

The results presented in table 1 shows that the error rate in evaluating varieties of the rice from the rice sample is much better in the proposed MATLAB method as compared with the error rate in manual inspection by 20 inspectors. In DC rice grain category, manual error is approximately 18%, while in MATLAB method, the error is reduced to 10%. Similarly, in SG rice grain category the error is 8% in manual category and 4% in MATLAB category. In the last category, LG shows the huge difference between both methods. Manual method gives 25% result, while MATLAB method has as low as 0% of error. These error differences show that the proposed MATLAB method is quite precise than the manual method of rice grain evaluation. It can be seen clearly from the achieved results that the proposed method is quite effective in recognition of the defective rice grains and it is cost effective as well.

Table1. Results of Proposed System

Rice Grain	Bench-mark	Manual Quantity	MATLAB-Data	%Error (Manual)	%Error (MATLAB)
DF	4	4	4	0	0
DC	11	9	10	-18.18	-10
SG	25	23	26	-8	4
LG	20	25	20	25	0

The following graph, in figure 5, shows the comparative analysis between the average data collected by

20 random persons with the MATLAB results and booth results is compared with the benchmark (known standard) to estimate the individual performances. In figure 5, it is clearly concluded that the performance of MATLAB data or proposed system data is much better than the manual evaluation of rice grain.

Fig. 5. Comparison of manual inspection method and the proposed system method

In figure 6. The error is evaluated with the comparison of benchmark (known standard) with the manual inspection data and automatic inspection data, to conclude the best performance of the proposed design.

Fig. 6. Error Analysis of manual inspection method and the proposed system method

In Figure.7, image processing method is used in evaluatuing different variety of the rice grains such as defected rice grains, discolored rice grain, short grains which are shown seprately in the GUI of the system, and the long grains. The system also helps in evaluating the number of defected rice, discolored rice, and short grain from the Rice sample and also provides the ratio of different qualities in the rice sample.

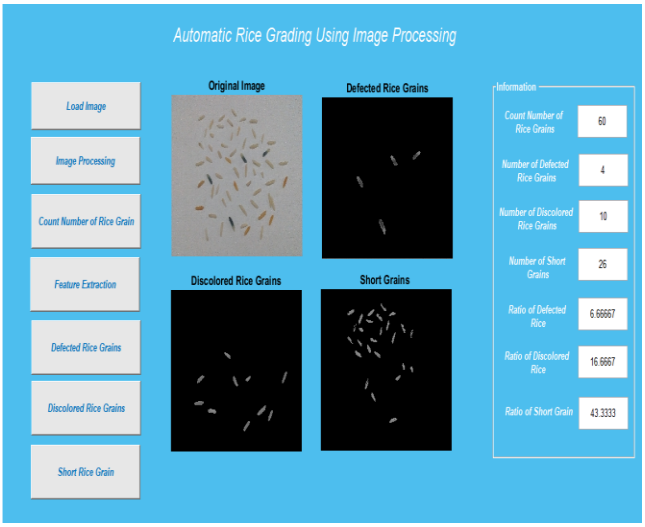

Fig. 7. GUI interface of Proposed system

V. CONCLUSION

In this paper, the idea is to propose cost-effective method for automatic rice grading machine. The proposed design consists of a mechanical structure with a camera mounted over it to capture the images of the rice grains spread over a tray, an algorithm to process the images of the rice grains and assess their size and color according to the quality grading standards, and a motor coupled with a controller to control the movement and to redirect the grains according to the grading criteria. The rice grains images are captured from the camera in JPEG format and are then fed to the MATLAB for image color conversion, filtering and feature extraction. The rice grain images are then assessed for four criteria's namely defected grain, discolored grain, short grain and long grain. A total of 60 rice grains were used in this experiment, and it was observed that the proposed method performs quite well as compared to the conventional manual inspection method. The advancement in the field of Artificial Intelligence and IOT has redefined the control and automation of the industrial processes in an efficient as well as cost-effective manner. In future, the quality assessment of all the industrial products may be effectively done by using Image Processing and Artificial Intelligence. Therefore, we suggest the use of Artificial Neural Network and Biologically Inspired Vision Algorithms for the controlling and automation of industrial processes and the quality assessment.

Since cost is an important factor which needs to be taken into account. The approximate cost of the proposed design is around 30 USD and with mechanical structure, it only costs around 400 USD, which is very much economical than the existing product. According to general market survey, China is producing these machines at a very high cost, i.e. around 10,000 to 13,000 USD [20] . Another online dealer of the rice grading machine supplies product in approximately 1000-1500 USD.

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