GRAIN QUALITY ANALYSIS USING IMAGE PROCESSING APPROACH

A Thesis submitted to Gujarat Technological University

For the Award of

Doctor of Philosophy

in

Computer Engineering

by

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Enrollment No: 119997493005

Under supervision of

Dr. Chetan B. Bhatt

GUJARAT TECHNOLOGICAL UNIVERSITY
AHMEDABAD

DECEMBER – 2017

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ABSTRACT

The significance of measurement of grain quality has been felt since way back to a century old. Cereal grains play an important role in meeting the nutrient needs of the human population. However, it is tedious, but very important to measure the individual kernel's qualitative analysis. It is important that a variation is provided within a sample in addition to average sample parameters measurement. Analyzing the grain sample manually is more time consuming and complicated process, and having more chances of errors with the subjectivity of human perception. It is also difficult to measure and memorize all individual parameters manually. In order to achieve uniform standard quality and precision, machine based techniques are evolving, solely on its prime advantage of reproducing the same qualitative result efficiency again and again. Recent developments in the field of image processing have opened up a wide scope of its use for sample analysis too. Various applications in Image processing are seen in the field of agriculture, biomedical engineering, food and drug industry and many others. Food application mainly caters the qualitative aspect of various food and dairy products.

In this research, efforts are made to investigate techniques used for the quality analysis. The main attempt is to compare the relative applicability of human v/s machine based approach of analysis. Machine based techniques can be further classified as, ***offline grain analysis technique*** and ***online grain analysis technique***. Both techniques are having their own limitations. Offline grain analysis techniques consume more time for sample preparation. On the other hand, online techniques suffer from less processing speed and kernel missing part while processing. Research gaps are identified with respect to the both techniques' limitations and new intelligent and accurate grain analyser technology is evolving to enhance speed and accuracy by removing deficiency of the existing systems. Moreover offline and online grain image analyser features can be combined and enhanced to prepare a fully automated grain analyser to deal with different kind of grain varieties.

The significance of size and color is in consumer acceptance of grain appearance. The price of the item depends on the color of the final product. Colors are the first parameters considered for quality by consumers. Consumer acceptance of grain and food highly depend upon the appearance. Appearance affects the quality of the grain. Wide research is going on for color and size measurement of the grain. Image analysis has proven the effective solution for measuring color based quality parameters. Though tedious, but it is very important to do the qualitative analysis and color measurement of the individual seed.

Grain quality strongly connected with the health of human being. So the grain quality related research directly helps society. The research is to provide a solution for the large scale grain quality measurement and provide new convenient, harmless and non-destructive base approach for the quality parameters measurement techniques. Techniques are evolved which eliminate the need of inefficient manual inspection and an automatic system relying on the machine vision is developed which allowed evaluating grain appearance quality. Research is done for size measurement and color calibration methods for image-based digital grain analysis. Size measurement is done from an angular position of the grain seeds. Color measurement is done for the colored base classification of grain seeds. The different grain organisation works with different grains and different grain varieties. So it is very difficult to provide different grain analysis solutions for them all. To deal with this, the calibration mechanism is provided. Different approaches are used for generating base data. This base data is prepared with the help of machine learning. This base data is then provided as input for actual process measurement. Experiments are carried out with different grain types, but with this research only focused at rice grain analysis.

To realize the approach, a software implementation is done in Microsoft .Net technology. The developed technology provides grain analysis for various grains, supports various standards, graphical reporting of grain analysis, and web based interface to support remote analysis.

Acknowledgement

First and foremost, I thank the God for giving me the light and for enabling me to complete this research work.

At first, my deepest gratitude to my supervisor, **Dr. Chetan Bhatt,** Principal, Government Engineering College, Sector 28-Gandhinagar for his consistent support, supervision, guidance and inspiration during my doctoral program. His invaluable suggestions and constructive criticisms from time to time enabled me to complete my work successfully.

The completion of this work would not have been possible without, the Doctorate Progress Committee (DPC) members: **Dr. Mehul Raval,** Asso. Prof., Ahmedabad University – Ahmedabad **Dr. Saurin Shah,** Principal, Silver Oak College of Engineering & Technology-Ahmedabad. I am really thankful for their rigorous examinations and precious suggestions during my research.

My gratitude goes out to the assistance and support of **Dr. Shishir Shah**, University of Houston, US., Ms. Mona Chaurasiya, Research Coordinator and other staff members of PhD Section, GTU. Further, I want to extend my special thanks to **Dr. Mehul K. Shah,** Head, Instrumentation and control department, **Ms. Mamata Patel,** lecturer Vishwakarma Government engineering college and **Dr. Kaushik K. Rana**, for providing me the right platform to add value in my career.

Also I am thankful to **Food Corporation of India - Ahmedabad** (FCI) and **Anand Agricultural University - Anand** (AAU) for providing support and guidance.

Most importantly, none of this would have been possible without the love and patience ofmy family members, especially my parents, **Shri. Narandas K. Dudhrejia**, my father, and **Smt. Niruben Narandas Dudhrejia**, my mother, **Mrs. Dhara Varun Sadhu**, my sister, and **Ms. Beena Narandas Dudhrejia**, my sister. My father, to whom this dissertation is dedicated to, has been a constant source of love, concern, support and strength all these years. My family members have aided and encouraged me throughout this endeavor. I would like to express my heart-felt gratitude to both of them. Finally, I have to give a special mention for the support given by my colleague **Mr. Rutvik Shukla**.

Table of Content

List of Abbreviations

ANN: Artificial Neural Network

CAC: Codex Alimentarius Commission

CCD: Charge-Coupled Device

DFPD: Department of Food & Public Distribution

DMI: Directorate of Marketing & Inspection

FAO: Food and Agriculture Organisation

GA: Grain Analyser

GSA: Grain size analysis

GSFA: codex General Standard for Food Additives

IRRI: International Rice Research Institute

LAN: Local Area Network

MC: Moisture Content

NIR: Near InfraRed

PLS: Partial Least Square

SC: Seed Count

WHO: World Health Organisation

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CHAPTER – 1

Introduction

The significance of measurement of grain quality has been felt since way back to a century old. Cereal grains play an imperative role in meeting the nutrient needs of the human population. Like any food, they are good to excellent sources of some nutrients and low or void in other nutrients. Though tedious, but it is very important to measure the individual kernel's qualitative analysis. Analyzing the grain sample manually is more time consuming and complicated process, and having more chances of errors with the subjectivity of human perception. In order to achieve uniform standard quality and precision, machine based techniques are evolved (Prajapati and Patel 2013), solely on its prime advantage of reproducing the same qualitative result efficiency again and again. Recent developments in the field of image processing have opened up a wide scope of its use for sample analysis tool(Hobson, Carter and Yan, Characterisation and identification of rice grains through digital image analysis 2007). Various applications in image processing are recorded in the field of agriculture, biomedical engineering, food and drug industry and many others. Food application mainly caters the qualitative aspect of various food and dairy producers. Image processing techniques were developed to classify plants and background pixels in images of rice plants acquired in a field experiment.

So forth, measurement of grain quality and cereal research with commodity crop such as rice, wheat, barley, corn, maize (Xu, et al. 2010) is wide research areas nowadays. Rice is one of the leading food crops of the world and is produced in all continents. Rice is comparatively high in caloric value and rice protein has a good balance of the essential amino acids. Historically and now through planned breeding, each grain type is associated with specific milling, cooking and processing characteristics. There are a number of varieties of each grain type in commercial production and new ones are continually in the process of being developed and released. Techniques are evolved to measure grain sample's quality based on it; samples can be classified in terms of productivity and price. Sample quality has also proven its significance in cereal breeding.

1.1 Background

Classification parameters vary based on consumer preferences. Grain quality depends on individual kernel features. Kernel's features can be measured by either compositional analysis or structural analysis.

Compositional analysis is useful for measuring internal aspects of the kernel such as oil, moisture, protein, fatty acid and amino acid. The quantitative models are useful for measurement. For compositional analysis generally, near-infrared (NIR) technologies and chemical analysis based technologies are preferred. Some expensive and time consuming biological DNA methods are also used for the analysis of rice quality. NIR technologies are used for detection of protein, fat, starch and water in the rice (Yang S 2015). The research was carried out to check sugar, fructose and glucose level in fruits using NIR technology (Bellon, Vigneau and Sacvila, Infrared and near-infrared technology for the food industry and agricultural uses: on-line applications 1994)(Liu, Kong and He 2012).With this study structural analysis is considered for quality analysis.

The structural analysis focuses on the outer part analysis. The structural analysis covers the visualization aspect like measurement of size (length, width, and height), color and glossiness (Ogata, Ukai and Kawai 2005). Structural analysis is done either by manual sorting or image-based analysis. Detailed measurement of seed shape characteristics such as length and width traditionally depends on laborious techniques such as manual measurement of individual seeds. Manual analysis is done either by naked eyes or using measuring instruments (Ramya, et al. 2010). In the manual measurement, the quality of measurement depends on analyser's experience/skills and the end results are influenced by work environment dynamics. Analysis results may vary if the samples to be analyzed are more in numbers. If the same sample is analyzed by two different analysers then there is a chance of variation in quality results. Only few attributes of quality parameters can be measured by observation of the grain sample. Broken kernel's examination can be made up to some extent with manual analysis. With this approach, only average parameters of grain sample can be measured, as it is not possible to individually identify and memorize the quality parameters of each individual kernel. For measuring the individual kernel's parameters, the image analysis techniques have proven as a very effective solution. As compared to sample analysis by visual observation, the instrument measurement has more accurate results. While measuring length or width of seed using vernier calipers or micrometer screw, if more pressure is applied; the edge of the seed gets damaged. Chemical analysis is also used for measuring grain quality sample. With this approach, for grain sample seeds undergo the chemical process as a part of sample preparation. After passing through a chemical process the actual parameters of the grain sample may alter. Due to this same, the same sample cannot be used again to check the repeatability of the analysis results. Non-destructive quality evaluation of food products is an important and very vital factor in food/agricultural industry (Maheshwari 2013). Alternative to this approach, image analysis techniques (Yao, Chen, et al. 2009)(Sansomboonsuk and Afzulpurkar 2006) are useful and effective solutions for structural analysis.

1.2 Motivation

It is important to understand the grain quality and its significance towards society. This section highlights the grain quality importance and related measurement techniques.

1.2.1 What is grain quality?

Quality can be defined as the combined features and characteristics of a product or service to satisfy stated or implied needs. Grain quality is a combination of many factors such as smell (aroma), size, cooking characteristics, color, nutritional value and percent whole grains.

It is the standard of agricultural products which gives buyers the opportunity to purchase exactly what they want (US Grains 2016). The quality of rice is not always easy to define as it depends on the consumer and the intended end use of the grain. All consumers want the best quality product that they can afford. The demand from the consumer for better quality rice has increased. Recently the trend has changed to incorporate preferred quality characteristics that increase the total economic value of rice. Grain quality is not just dependent on the variety of rice, but the quality also depends on the crop production environment, harvesting, processing and milling systems. The quality characteristics of paddy and milled rice can be considered separately. These properties are playing an important role in rice quality, marketing and exporting. Rice quality is a combination of physical and chemical characteristics which are required for a specific use by a specific user (IRRI 2017).

1.2.2 Why grain quality is important?

Quality of grain is of great importance for human beings as it directly impacts the human health. Hence there is a great need to measure a quality of grain and identifying adulteration / non-quality elements. Grain quality can have different meaning to different people depending upon the type of grain or seed and its intended use. Several important factors affect grain quality, including phenotypic expression, environmental conditions, harvesting and handling equipment, drying systems, storage management practices and transportation procedures (Grain and Seed analysis - ASDInc - PANalytical 2017). Whole grains are rich sources of vitamins, minerals and dietary fiber all of which may have individual, synergistic or additive actions that positively affect health. In addition, whole grains' photochemical complement the phytochemicals in fruits and vegetables when they're consumed together. So it is mandated to identify the size of the kernel in grain sample.

Lower quality grain in daily food can cause serious disease. Sometimes the lower quality grain is mixed with good quality grain to get a higher price. The product made from this kind of mixture can lead to poor quality foods. This kind of adulteration must be identified while the selection of grain.

Consumer preferences (e.g., a preference for a certain smell or whiteness of grain) affect what people buy and so affect market prices. Therefore it requires different kind of grain analyser which can provide analysis to satisfy the market needs. (Rice Knowledge Bank - IRRI 2016).

1.2.3 Conventional Techniques

Grain shape is evaluated with length, width, and the ratio of length and width of rice grains. At present, the length and width of rice grains are usually measured by an inspector using a ruler or a micro-meter. For measuring quality of grain sample, examiner needs to get few seeds from sample and do the analysis. But for measuring length and width of even few seeds, by placing them in one grain tray and measure the length and width of each seed one by one, is very tedious task and takes lots of time.

Rice chalkiness is also estimated by the naked eyes of an inspector. Outcomes from different inspectors or inexperienced inspectors may vary at an unacceptable range. So it is a neither objective nor efficient way in evaluating rice appearance quality relying upon manual method.

A new scientific era has emerged with great grain quality image processing instruments which can help in the categorization of grain samples and get an attractive price from consumers for the food industry, especially in Asia. Machine vision and image processing are widely used in biological and agricultural research with the improvement of computer technology and significant reduction of the cost of hardware and software of digital imaging. Many researches applied machine vision to estimate rice appearance quality inspection. There are various food varieties like rice, wheat, potato, soya bean and maze. The rice and wheat being commodity crops are important among all the grains.

These researches provided some new ideas and image processing methods for evaluating rice appearance quality. The effectiveness and accuracy of inspections have been improved through these methods. But some factors might affect the outcomes of inspection for rice appearance quality using machine vision and still remains unsolved. For example, the inspection environment, light source, image processing method could result in an inconsistent and low accuracy of inspecting outcomes. With this research, new evaluation system is developed for inspecting the rice appearance quality based on machine vision. With this work new sample preparation technique is introduced and color calibration mechanism is provided to deal with different standards defined by various organisations. Web based implementation is provided to use this system globally. The developed system is non-destructive and is an alternate to human visual assessment.

1.3 Outline of the Thesis

The rest of the thesis is organized into chapters as follows:

Chapter 2 provides the research literature review related to physical aspects of grain quality. First, it highlights the structure of rice grain structure and grain quality parameters which affect the grain quality. Subsequent discussion is made on manual techniques used for grain analysis. Then it focuses on the offline and online image-based grain analysis techniques available in markets. The limitations of different types of techniques are discussed in subsequently. Next, different grain analysis standards and market specification worldwide are studied. Based on literature review research gap is identified and scope is defined for the research.

Chapter 3 presents the experimental setup and architecture detail of developed system. It also depicts the issues which are emerged by the proposed architecture and subsequently its solutions.

In ***Chapter 4*** detail discussion is made on size measurement and chalkiness measurement of the developed grain analyser.

Chapter 5 gives the idea about color calibration mechanism implemented in the developed system. Subsequently, different kinds of approaches used for this color calibration are discussed. Finally, the comparison of both approaches is elaborated.

Chapter 6 highlights the adulteration in grain samples and related techniques for that. The methods for identifying the adulteration in developed system are discussed. Different approaches are discussed for realizing adulteration analysis.

Chapter 7 shows the desktop/offline implementation of research work. It gives idea about the phase wise implementation of grain analyser. All graphical user interfaces and functionalities of developed grain analyser are discussed in this chapter.

The system is made web based for universally acceptance, the discussion of the implementation is described in ***Chapter 8***. Architecture, workflow and graphical interface of developed grain analyser are depicted in this chapter.

Chapter 9 shows the testing results and discussion.

Finally, conclusion and future enhancement are elaborated in ***Chapter 10***.

CHAPTER – 2

Grain Quality Analysis

2.1 Introduction

Cereal grains play an important role in meeting the nutrient needs of the human population. They are good excellent sources of nutrients. Pulses are nutrient-rich foods; containing dietary fiber, protein, carbohydrates, b-group vitamins and minerals such as iron, zinc, calcium and magnesium. The quality of cereal products is determined by a variety of characteristics which may be assigned different significance depending on the desired end use or type of product.

The quality of grain is defined in context of its content elements such as protein, carbohydrate, etc. as well as in context of its physical features. This work is focused on the physical aspects involved in the grain analysis and therefore this chapter presents the research carried out in the area of physical feature analysis, and issues are to be addressed.

This chapter first presents different kind of grain analyser techniques used in physical analysis of grains found in literature. It mainly includes manual and machine based techniques. Both techniques are further classified into different categories. All techniques have their own limitation and advantages which are discussed in subsequent sections.

With this research prime focus is made on rice quality analysis. This analysis technique is also useful for quality analysis of other types of grain by configuring various parameters.

2.2 Rice grain structure (Haifa 2017)

To understand rice seed in depth it is required to understand its biometric properties. Fig 2.1 shows the cross section of rice seed.

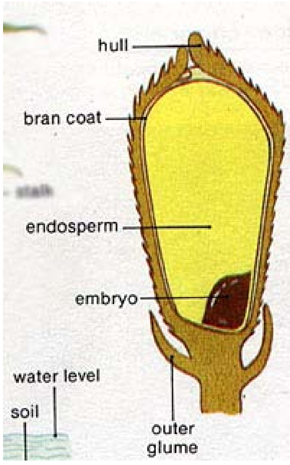


FIGURE 2.1: Cross section of rice seed

A kernel of rice consists of a hull and a bran coat, both of which are removed by polishing "white" rice. ***Rice shell, hull or husk:*** *e*ncloses the bran coat, the embryo and the endosperm. ***Bran Coat (layer):*** a very thin layer of differentiated tissues. The layer contains fiber, vitamin B, protein and fat. The most nutritious part of rice resides in this layer. ***Embryo:*** The innermost part of a rice grain consists mainly of starch called amylase and amylo pectin. The mixture of these two starches determines the cooking texture of rice.

Seed is a living product that must be grown, harvested, and processed correctly in order to realize the yield potential of any rice variety. Good quality seed can increase yields by 5-20%.

Rice seed quality is not only important for eating but it is also significance for plantation. Cultivation with good quality seeds can provide better crop product. For grain quality measurement it is important to study the quality parameters of seeds which are described next.

2.3 Grain Quality Parameters

For any grain seed, there are many parameters which are very important and directly mapped with grain quality. Rice quality is primarily assessed based on physical properties such as head rice identification, chalkiness, grain size and shape, and premium quality traits such as color have extra value. Below mentioned parameters are having ample significance and can be measured by image processing techniques.

2.3.1 Length and Width

Grain size and shape is a varietal property. Long slender grains normally have greater breakage than short, bold grains and consequently have a lower milled rice recovery. The grain dimensions also dictate to some degree the type of milling equipment needed. For instance, the Japanese designed milling equipment may be better suited to short bold japonica grains whereas Thai made equipment will be more suitable for longer, slender grain types.

Rice shape and chalkiness characteristics are very important to evaluate the rice appearance quality because they are the key factors for rice quality and pricing. Thus, it is necessary to have the accurate information about rice appearance quality.

The ***length*** and ***width*** of a rice grain are important attributes that determine the class of the rice. There are three main classes of rice, based on grain length: short, medium and long. In terms of width, Arborio styles are generally the widest, followed by short, medium and long.

Length and width of grain are critical parameters for grain samples classification. The quality of grain sample has a mapping with structural parameters mainly with length and width. Different organisations have their own classification criteria based on size measurement. The analyser is developed which can provide different classifications based on organisation selection. Grains are classified as the short grain, medium grain and long grain. The length and width of a rice grain are important attributes that determine the class of the rice.

Based on ARSO (CD-ARS 464:2012(E)) (ARSO : ARS 464 (English) : Milled Rice Specification 2012) – African Rice Standard Organisation, grain seeds are divided into head, broken and chip seed. Broken seed is further classified in long broken, medium broken and small broken. For CODEX STAN 195-198 (Codex Standard for Rice: CODEX STAN 198-1995 1995) standards the grain seed is classified in long seed, medium seed and small seed.

The prime consideration in sorting the grain shall be given to thin kernels due to its softness. Based on this phenomena trend is set for improved milled rice yield and head rice yield. ***Long-grain*** brown rice fluffs up readily and tends to separate while cooking. Because of this quality this kind of rice is the choice for pilafs, casseroles, salads and baked dishes. It also has a firmer, dryer texture and feel in the mouth. That means rice will fall apart, rather than stick together. ***Medium-grain*** varieties are stickier and a good choice for paella, a pungent Spanish dish that incorporates seafood and meat and stuffing for vegetables. ***Short-grain*** brown rice has a bit creamy texture that lends itself well to dishes such as risotto rice pudding. Weight provides information about the density of grain; moisture retains capacity and cooking capacity. Two samples have a different quality which is having the same look in size but different in weight. These discussed features of rice are useful for agricultural breeding and categorization of grain for market delivery.

2.3.2 Aspect Ratio

Grain shape is the very substantial property of the grain, which is mostly defined by the aspect ratio (length-width ratio). ***Aspect ratio*** is basically the ratio of the length of seed to the ratio of the width of the seed.

$$\textit{Aspect Ratio} = \textit{Length of kernel } (L) \,/\, \textit{Width of kernel } (W)$$

For any grain sample, generally average value is considered:

$$\textit{Aspect Ratio}_{avg} = \textit{Average length of kernel } (L_{avg}) \,/\, \textit{Average width of kernel } (W_{avg})$$

Aspect ratio generally measured in millimeter. Classification of seeds depends on the aspect ratio i.e. based on seed length/width ratio.

The appearance mostly depends on aspect ratio of a product that can be an important selling factor and affect sales. Consumers are often fickle, so even though a product may have excellent nutritional quality, it may not sell if it is unattractive. The appearance of a field crop is often affected by harvesting practices. Staining, weather damage or mechanical damage reduces the visual quality. Mechanical damage also affects the storage characteristics; broken grain attracts mold and insect damage. Grain sample categorization can also be done using a combination of the seed length and the aspect ratio. The aspect ratio is universally accepted to describe the shape and class of the grain variety. The other important aspect of length and width is uniformity all the grains in one sample must look the same. The samples which have uniformity in length and width in first look have higher price benefits (Kaur and Singh 2013).

2.3.3 Texture

The texture is an important characteristic for every grain types. It defines as the common repetitive patterns. It has some tonal primitives which are common across many seeds. Image texture can be calculated based on one or more of the properties of fineness, coarseness, smoothness, granulation, randomness or irregularity. Rice research and development programs in Louisiana and Arkansas, in the USA, are attempting to identify instrumental methods that correlate well with scores reported by sensory panels for the different textural characters (International rice research institute 2006).

Texture describes what we might experience in our mouths when eating rice: initial mouth feel, hardness, adhesiveness, cohesiveness, springiness, resilience, gumminess and chewiness. These characteristics are generally measured by a sensory panel, a group of people who are very experienced in determining and describing the texture of rice. Flavor and aroma also have an indirect mapping with the texture of seed. The aroma of cooking rice may be described as hay like/musty, popcorn, corn, alfalfa grassy green bean, dairy, sweet aromatic(fairy floss, caramel), grassy, vanilla, sewer, animal, metallic and floral.

2.3.4 Chalkiness

Chalkiness is the opaque area in the rice grain. If part of the milled rice kernel is opaque rather than translucent, it is often characterized as "chalky". A chalky grain means the grains at least half of which is milky white in color and brittle in nature. It is undesirable in almost every market. Chalky areas occur because of malformed starch granules with air spaces between them. Chalky areas cook differently from translucent areas, but only a very clever palate could detect them. Broken and fragments include pieces of rice kernels which are less than three fourth of a whole kernel.

Chalkiness disappears upon cooking and has no effect on taste or aroma, however it downgrades milled rice. Excessive chalkiness is caused by interruption during the final stages of grain filling.

Chalkiness can be calculated as below:

% chalky grain = (no. of chalky seed/ no. of total seeds) X 100

2.3.5 Whiteness

In milling, the whitening and polishing greatly affect the whiteness of the grain. During whitening, the silver skin and the bran layer of the brown rice are removed. Polishing after whitening is carried out to improve the appearance of the white rice. During polishing, some of the bran particles stick to the surface of the rice which polishes and gives a shinier appearance. Fig. 2.2 shows the different milling degree percentage in rice grain while milling process.

FIGURE 2.2: Milling degree due to amount of bran removed in milling process (IRRI 2017)

2.3.6 Damaged / discolored grains

Damaged grains are grain seeds which are different in look and having lower nutrition values through a biochemical change in the development of off-odors and changes in physical appearance. These types of damage are caused because of moisture content, pest damage, physical damage, insects, and heat exposure. Damaged/discolored grains include broken, fragments of whole that are internally damaged or discolored, immature, yellow, red or green color seed.

It can be measured as:

% damaged grain = (Total no. of damaged seed / total no. of seeds) X 100

2.3.6.1 Breakage and cracking

Overexposure of mature paddy to fluctuating temperature and moisture conditions leads to the development of fissures and cracks in an individual kernel. Cracks in the kernel are the most important factor contributing to rice breakage during milling. This results in reduces milled rice recovery and head rice yields.

In some seasons, ***cracking*** of the rice grain is a significant problem. Most cracking occurs in the field and seems to be related to changes in grain moisture or to moisture cycles after the rice matures. Chalky grains are softer than translucent grains and are more likely to break during milling. Rough handling of grain during harvest operations and during drying and processing will also cause the grain to crack. Cracking decreases head rice yield because cracked grains often break during milling. Most markets require whole or unbroken grain; therefore cracked grain can reduce payments received by the grower and the miller.

Cracking also decreases the cooking quality of the grain. Grains that are cracked but remain intact during milling are deemed visually undesirable. Furthermore during cooking, the starch leaches out of cracked grain and collects as a sticky layer on the bottom of the rice cooker. If rice is cooked by the rapid boil technique, the starch leaches from the rice into the cooking water.

2.3.6.2 Immature

The amount of immature paddy grains in a sample has a major effect on head rice yield and quality. The immature rice kernels are very slender and chalky and this results in excessive production of bran, broken grains and brewer's rice.

2.3.6.3 Yellowing

Yellowing is caused by over-exposure of paddy to wet environmental conditions before it is dried. This results in a combination of microbiological and chemical activity that overheats the grain. These fermented grains frequently possess partly gelatinized starch cells and nearly resist the pressures applied during grain milling. While the presence of fermented grain does not affect milling yields it does downgrade the quality of the milled rice because of the unattractive appearance.

2.3.7 Adulteration

Adulteration means the presence of foreign matter or non-quality elements in grain sample. Foreign matter includes dust, stones, lumps of earth, chaff, stems or straw and any other impurity. Other grains include those which are not the actual grain.

Lower quality grain is also used as an adulteration. Adulteration can cause serious diseases if consumed with daily foods. Sometimes lower quality grain is mixed with good quality grain to get a better price from the customer. While choosing grain product, this kind of adulteration must be identified.

2.3.8 Yield

Yield is the most noticeable characteristic to farmers while the crop is in the ground, but when the product of the crop, the milled rice, reaches the market, quality becomes the key determinant of its sale-ability.

Head rice yield (HRY) is one of the primary factors that currently determine the official market grade of rice. Head rice, or the whole kernels in a well–milled rice sample, is defined by the USD a Federal Grain Inspection Service (1999) as, “Unbroken kernels of rice and broken kernels of rice, which are at least three–fourths of an unbroken kernel.”HRY is the weight percentage of a rough rice sample that remains as head rice after complete milling. Head rice is generally worth twice as much as the broken kernel classes of brewers, second heads, and screenings. Thus, HRY primarily determines the economic value of rice since it is an indicator of the milling quality of a rice lot. End–users of rice pay premium prices for head rice and typically specify maximum tolerances of percentage broken kernels for any given sale. Because of the importance of HRY as an indicator of rice quality, accurate HRY measurement by laboratory milling tests is essential. Therefore, a precise and accurate measurement of HRY is important to producers, processors, and end–users of rice. (Cnossen, Siebenmorgen and Yang 2000)

“Head rice” or head rice percentage is the weight of head grain or whole kernels in the rice lot. Head rice normally includes broken kernels that are 75-80% of the whole kernel. High head rice yield is one of the most important criteria for measuring milled rice quality. Broken grain has normally only half of the value of head rice. The actual head rice percentage in a sample of milled rice will depend on both varietal characteristics (i.e. the potential head rice yield), production factors, and harvesting, drying and milling process. In general harvesting, drying, and milling can be responsible for some losses and damage to the grain.

2.3.9 Weight

Grain ***weight*** provides information about the size and density of the grain. Grains of different density mill differently, and are likely to retain moisture differently and cook differently. Uniform grain weight is important for consistent grain quality. Two samples have a different quality which are having the same look in size but different in weight.

These all parameters are provided technical meaning based on that any grain sample quality can be defined. A subsequent paragraph throws light on related technical terms for rice grain analysis.

2.4 Technical Terms

In this section we discuss various technical term which is useful for grain quality analysis.

- ***Rice*** means non-glutinous and glutinous rice (Oryzasativa L.) in whatever form.
- ***Paddy or rough rice*** means rice that is not yet dehusked. Paddy or rough rice is a similar term for paddy, or rice retaining its husk after threshing. Under-milled grain means grain whose bran portion is not completely removed during polishing or which has substantial bran streaks left on it.
- ***Brown rice or husked rice*** means paddy from which the husk has been removed.
- ***Green grains*** mean kernels, whole or broken, which are greenish in color.
- ***Cargo rice*** (Loonzain rice, Brown rice, Husked rice) means rice that is dehusked only.
- ***White rice*** means rice that is obtained by removing bran from cargo non-glutinous rice.
- ***Whole kernels*** mean rice kernels that are in the whole condition without any broken part.
- ***Head rice*** means broken kernels whose lengths are more than those of *broken* but have not reached the length of the whole kernel. Milled rice with length greater or equal to three-quarters of the average length of the whole kernel
- ***Broken*** means broken kernels which don't reach the length of Head rice. This includes splits kernels that retain the area less than 80% of the whole kernel.
- ***Red kernels*** mean rice kernels that have red bran covering the kernels wholly or partly.
- ***Yellow kernels*** mean rice kernels that have some parts of the kernels turn yellow obviously.

- ***Chalky kernels*** mean non-glutinous rice kernels that have an opaque area like chalk covering the kernels as from 50% onward.

- ***Damaged kernels*** mean kernels that are previously damaged as can be seen by the naked eyes due to moisture, heat fungi, insects or other.

- ***Undeveloped kernels*** mean kernels that do not develop normally as should be and are flat without starch.

- ***Immature kernels*** mean rice kernels that are light green, obtained from immature paddy.

- ***Other seeds*** mean seeds of other plants other than rice kernels.

- ***Foreign matter*** means other matter than rice. This includes rice husk and bran detached from rice kernels.

- ***Milling degree*** means the degree to which the rice is milled.

2.5 Manual Techniques for Grain Analysis

In manual techniques, grain sample is analyzed with necked eyes. For measuring dimensional parameters, usually micrometer screw and vernier calipers are used. The results with these technologies are very subjective and also depend on expertise level and mindset of the analyser. Results might be varying with the same analyser based on analyser's experience level and mood. For the same sample and for the same analyser there is a chance of different results with repetitive measurement of the same sample. So results would not be more reliable. Moreover, if we are interested in individual seed's parameter then it is very time consuming and tedious in manual measurement with micrometer screw and optical inspection. It is very difficult to measure quality parameters and remember every seeds' features individually. Average features like length, width, color and no. of broken seeds are generally measured with this method. The centered white color part called rice's chalkiness is also sometimes distinguished with the manual technique. There is an also possibility of material damaged and deformation. It becomes more tedious when many samples need to be analyzed. The inexperienced human analyser may provide results in the unacceptable range. Therefore, it is the inefficient way to measure rice appearance using manual techniques.

Manual analysis is highly subjective and affected by physiological conditions of human and other environment configurations which result in erroneous results.

Next section describes semi automated techniques for measuring grain quality analysis.

2.6 Grain analysis methods

Cereals are having different nature in shape because of that the same size measurement techniques might not be useful for all different types of cereals and its varieties. Top level shape based seed classification can be done for below two types (Mandal, Roy and Tanna 2012) :

Approximately circular seed: The seed having length and width nearly equal to same and circular kind of look. If we draw surrounding polygon for filling it then it would have square in shape from two dimension i.e. peas, soybeans.

Non-circular seed: The seeds having much difference in length and width. If we draw surrounding polygon for filling it then it would have rectangle in shape from two dimension i.e. kidney beans, cranberry beans, rice and wheat.

Grain size analysis (GSA) is a practical and straightforward process that provides you with critical data need to make informed decisions. The particle size has many implications on the digestion and performance of poultry (Amerah, et al. 2007).Seed size is an important parameter for plant growth and yield. Various researches are made for factors influencing pellet quality (Behnke 2001) (Garcia-Maraver and Carpio 2015) (Stark 2010). Various kinds of different techniques are used for grain size analysis like screening, sieve shaker, hydrometer, cyclosizer, laser diffraction, and methylene iodide (Grain-Size-Analysis.aspx n.d.).

Sieving Method

Sieve analysis is used to divide the granular material into size fractions and then to determine the weight of these fractions. Percentage of grain size can be determined using sieve and hydrometer analysis (CME315 Soil Mechanics Laboratory - Chicago 2015) (UCMerced University 2014) (NinoLab-The Basic Principles of Sieve Analysis 2014). Method used for these techniques is D 422 – 63 (Reapproved 1998) (Tecnico Lisboa - Particle size 1998).With this method sample is pour into tower of sieves as shown in Fig.2.3 (a). It contains mechanical shaker at base as depicted in Fig. 2.3 (b). In a typical sieving practice, a set of sieves with different hole sizes is used to separate seeds into various size categories at each level. At each level there would be chronological order change in size.

FIGURE 2.3: (a) Set of sieves (b) Sieve shaker

There are different types of sieving methods provided by **Retsch GmbH & Co.KG** (The Basic Principles of Sieve Analysis - Ninolab 2004) (Voicu, et al. 2013) :

1. ***Manual and mechanical sieving:*** With manual method no electricity supply is used. The manual action is generated using mechanical energy in mechanical sieving. It is further classified in ***throw-action sieving*** and ***horizontal sieving*** based on rotation directions.

2. Single sieve and sieve set sieving: This is only used to determine the percentage of undersize and oversize particles. It is not useful for particle size distribution. In a single sieving process, only a single sieve with a defined mesh is subjected to the sieving movement together with a collector pan. It is normally used only for orientation purposes.

At each stage particles/grains of different size can be found. The sieving method is also useful for corn particle size measurement as shown in Fig. 2.4 (Stark 2010).

FIGURE 2.4: (a) split sample (b) sample before rotating (c) rotating (d) sample after rotating

However, this method is not accurate as there is chance that grain seed is passing through in vertical position. This type of method is generally useful for circular or approximately circular seeds (Mandal, Roy and Tanna 2012). Sieving method is used for sesame analysis after de-hulling sesame seeds (Elleuch, et al. 2007). This type of methods is widely used in particle size analysis and it will not provide the information related to other features such as aspect ratio, colour, chalkiness etc.

In last decade image based grain analysis has gain acceptance and various techniques are developed. Image based grain analysis can provide multiple parameters analysis using captured image of the grains under test. The next section presents various techniques for grain analysis based on image processing approach.

2.7 Conventional Image Based Grain Analysis Techniques

Recent technological development in the field of image processing has made it more adaptable and accepted method for feature extractions in grain quality analysis. In current technological innovations, image-based analysis has proven of great significance in solving the day to day problems. With image based grain analysis, grain seeds are put/spread over grain tray or conveyer belt. Grain sample image is taken either by scanning (using scanner) or by capturing (with different types of cameras). This image is processed for feature extraction of every seed. To get better results pre-processing is performed on captured image. Based on each seed's extracted features of grain sample image, the sorting is performed.

Image based grain analysers can be classified in following two categories:

1. *Offline grain analysers*

2. *Online grain analysers*

In both the techniques grain sample image is captured for processing. In online grain analyser, the grain would be in moving condition while capturing the grain sample image. While in offline grain analyser the grain would be in steady condition while capturing the grain sample image.

Different offline/online image based grain analysers are studied. Subsequent sections discuss the methodology and limitations associated with each type of grain analysers.

2.7.1 Offline Image Based Grain Analysers

Offline image based grain analyser captures the image of grain sample, while grain sample is in the static condition. Offline analysis of grain initiates with placing the individual kernel into grid organized into rows and columns on a structure. The person must have to manually put the single kernel on a grid element.

Next section describes the offline image based grain analysers which highlight the working functionalities of grain analyser; hardware/software used with it, related issues and associated advantages of each grain analyser.

2.7.1.1 Digital Image Analysis (DIA) – SeedCount 324 (Armstrong, et al. 2005)

The research article on SeedCount 324 DIA (Digital Image Analysis) systemdemonstrates the use of a specially developed imaging tray(Armstrong, et al. 2005). Weiss Enterprise, Australia in their research manual demonstrates seed count measurement of various grains along with its significance(SeedCount-Ltd. 2006). The use of SeedCount image analyser allows easier collection of data from large numbers of grains. The tray also allows direct measurement of kernel thickness.

SeedCount 324 DIA system – developed by SunRice, through the Rice Appraisals Laboratory in Leeton NSW, does the careful placement of grains sampled with a vacuum based positioning funnel. After capturing the image, it is analyzed using algorithms to measure the kernel length, width and related parameters.

In this technique, grain seeds need to be put in one grain tray. Grain tray is having slots in rows and columns like structure. Grain sample is gently spread on grain tray, and then all kernels are separated to fit one kernel in one single slot of grid tray. Each slot must accommodate only one kernel while capturing the image, as every slot is directly mapped with a particular address for image analysis. Fig. 2.5 (a) shows the grain tray which needs to be filled by grain seeds. Grain seeds are fit in different grid kind structured slots. Fig. 2.5 (b) shows the SeedCount scanner.

FIGURE 2.5: (a) SeedCount tray preparation (Armstrong, et al. 2005)

FIGURE 2.5: (b) SeedCount tray in scanner cabinet(Armstrong, et al. 2005)

The limitation of this technique is that it does not deal with the connected seeds. It requires separating all kernels manually, taking much time for sample preparation. It doesn't measure the real length and breadth but it measures a diagonal approximation. The DIA system is useful for examining larger samples, as up to 1350 rice kernels can be examined per tray. This data is useful for comparing the dimensional distributions within and between grain lots and to briefly examine the effects of milling on rice. It is very tedious to arrange all 1350 kernels at a place to get the accurate result. The angular position of seed is one of the affecting factors to results. This method is difficult to apply when a huge number of samples need to be measured and there is a possibility of kernel damage.

Rice image is captured from the top; it could give different results if angels of the camera are varied. The weight of seed is not considered while analysis. As weight also affects the quality, there should be few techniques to categorize seed based on individual weight. Image smoothing could be used before applying extracting features. Cut rice identification needs to be made to improve quality results. More specific development methods are required for various rice types such as Basmati, lachkari etc. Chalkiness of rice one of the important factors for measuring rice quality might be considered for better results (Guangrong 2011).

2.7.1.2 Image acquisition system (Guzman and Peralta 2008)

The interesting work in the classification of rice has been recorded at Cagayan state University, Philippines under experiment conducted by (Guzman and Peralta 2008). This research investigates the use of a machine vision system and multilayer neural networks for automatic identification of the sizes, shapes, and variety of samples of 52 rice grains belonging to five 5 varietal groups of rice produced in the Philippines. Several multilayer neural networks are developed for sizes, shapes and varietal type's classification using thirteen 13grain features extracted from each sample image.

While capturing the image, grains arranged in a singulated non-touching pattern for each rice variety as shown in Fig. 2.6. So here there is a limitation of arranging all seeds at a particular location which is a tedious task if many samples need to be analyzed. With this method, classification needs to be improved more by combining it with machine vision system. Sampling methods, sample processing and sample size should be standardised according to rice industry standards.

FIGURE 2.6: Pictorial of image acquisition system (Guzman and Peralta 2008)

2.7.1.3 Rice Quality Analyser RN300 (Kett – RN300 2009)

Rice Quality Analyser– kett – Model RN300 grains works on reflected lights fundamentals (Kett – RN300 2009). Rice quality analyser developed by Kett services private limited; Santiago Boulevard incorporates the measurement using numeric and optical techniques. The assessment outcome is both quantitative and qualitative.

Measurement tray can accumulate 1148 grains in one tray. Tray contains 1148 holes; each hole in the tray has an address. The address is based on row and column position of the tray. It has the color code for identification and verification. Tray fits into the scanner for further processing. The light is transmitted on sample and reflection of light by each seed is measured. For every sample, RGB signal is taken and processed by "Quality Scan" software. For every sample, data is compared with pre-defined standards and each kernel is analyzed. Based on that summary of sample quality is prepared and results are transferred to the computer. It takes 24 seconds to complete this operation. Fig. 2.8 shows the mapping of a kernel in pictorial representation computer system with the physical tray slot in the tray.

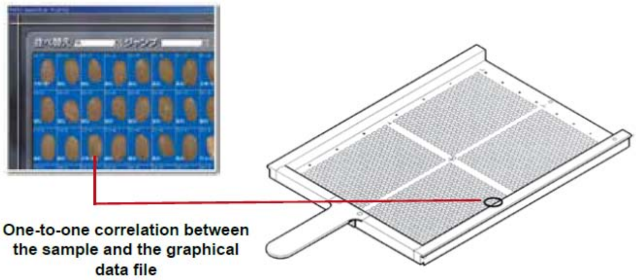


FIGURE 2.7:Pictorial of image acquisition system (Kett – RN300 2009)

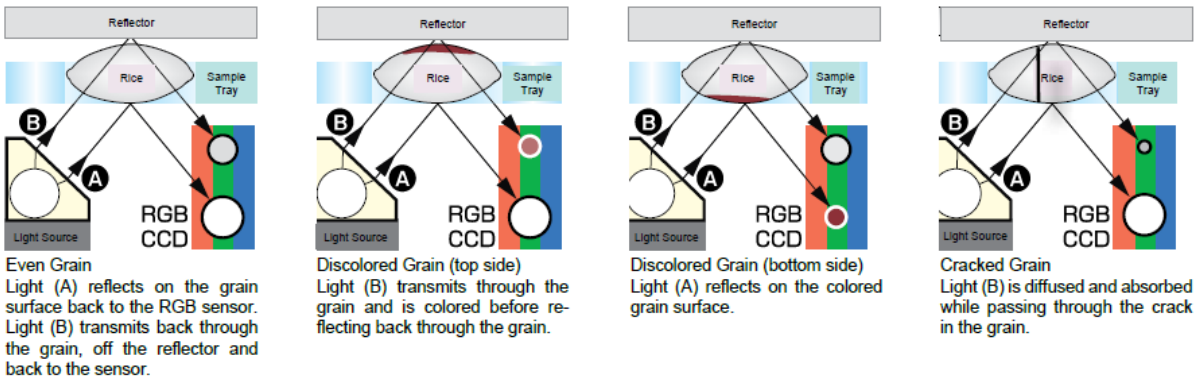


FIGURE 2.8: Different grain type reflection (Kett – RN300 2009)

It is required to make careful placement of each grain seeds before start processing. The result depends on transmitted light, so it depends on the intensity of light source. It classifies the grain seed as even grain, discolored grain top side, discolored grain bottom side and cracked grain as shown in Fig. 2.8. The result might be varied based on the selected light source.

2.7.1.4 Many other offline image based grain analysers

The significance of chalkiness of rice has been touched upon in the article “Rice Kernel Chalkiness and Milling Quality Relationship of Selected Cultivars” by (Bautista, Siebenmorgen and Counce 2012). The study quantifies the level of chalkiness and the correlation to head rice yield (HRY) of two medium-grain cultivars, ‘Bengal’ and ‘Jupiter’, and four long grain cultivars, ‘Cypress’, ‘LaGrue’, ‘Wells’, and ‘XL723’. These variants were hand-harvested over a range of moisture contents (MCs) from five locations in Arkansas in 2007 and 2008.The noticeable work to record the chalkiness of rice is published in the research article of (Yoshioka, et al. 2007). The work evaluates the effectiveness of image information processing with an inexpensive personal computer and a digital image scanner to measure and categorize chalkiness and assesses the method’s viability as an alternative to human visual assessment.

The research article “An Improved Canny Edge Detection Algorithm Based on DCT” (Zhao, Liu and Wan 2015) suggested a new method that replaces the traditional Gaussian filtering step in the canny algorithm. In this method, the DCT coefficients are nonlinearly shrink to achieve the de-noising effect.

Some of the remarkable work for the analysis rice kernel is by (Chiang, Liao and Lu 2016). Research article (Welna, Szymczycha-Madeja and Pohl 2015) compares the strategies for sample preparations prior to spectrometric measurements for determination of rice kernel’s qualities. In the research (Lemus, et al. 2014)efforts are made to identify bioactive components from the rice brand in their research article. Various by-products of the rice industries such as rice brands and rice brand oil has been of significance attendance in the recent time by various researchers.

The research, (Facco, Masiero and Beghi 2013) summarized various technological advances on multivariate image analysis for product quality monitoring and the work is published in the journal of process control vol. 23. The noticeable work in the field like (Villez, Venkatasubramanian and Rengaswamy 2013) to generalised shape constrained spline fitting, (Mollo, et al. 2016)to analyse individual differences of the neurocognitive architecture of the semantic system, (Awad, et al. 2012) to list out the applications of ultrasound in quality control of food and (Jiang and Liu 2011) to study the pre-treatment method for grain size analysis of red mudstones.

2.7.2 Offline Image Based Grain Analyser Limitations

In all the offline grain analysers, it is necessary to put grain kernels in specific positions, in grid kind structure. The grid contains slots in row and columns arrangement. Each slot can accommodate one seed at a time. All slots are mapped with a particular address, which can be used to be located by image analysis software. With this methodology, it is required to separate all kernels manually before starting the analysis. If a huge amount of samples are there then sample preparation becomes a too tedious task. If the seeds are not put in individual slots then there is a chance of considering more than one seeds as one seed, which affects quality results. So, all seeds should be separated precisely. Few grain analyser uses flat scanner but they are separating all individual seeds manually, this can also have same limitations as discussed with predetermined grid structure mechanism (Shouche, et al. 2001).

Offline grain analysers deal with few rice varieties only. The reason is, to deal with different rice varieties the tray slots size should be variable, which is not possible with static frames. For such kind of method (seed scan) (Armstrong, et al. 2005) generally different frames are provided containing different size slots. Sample weight should be considered, which can be further mapped to quality parameters indirectly. It is also required to set configuration variables. If they are not set properly then results would vary for the same sample analysis. Chalkiness is one of the important factors for rice which is not considered with many offline grain analysers.

2.7.3 Online Image Based Grain Analysers

Online image based grain analyser captures the image of grain sample, while grain sample is in moving condition. Below is the summary of the offline image based grain analysers which highlights the working functionalities of grain analyser, hardware/software used with it, related issues and associated advantages of each grain analyser.

In online grain analysis, the speed of processing including image acquisition becomes most essential as the kernels are in motion. The technique is only adoptable when the supported hardware has fast processing speed.

2.7.3.1 HRY grain check system - GrainCheck310 (Wang, et al. 2005)

In HRY grain check system - GrainCheck310, has also bought significance of light illumination for grain quality analysis. In this study, images of durum wheat kernels were captured under three illumination conditions (reflected, side – transmitted, and transmitted) and these images were used to develop artificial neural network models to classify durum wheat kernels by their vitreousness. Based on their vitreousness artificial neural network model is develop to classify durum wheat kernels. It shows 100% classification results for non-vitreous kernels and 92.6% for mottled kernels based on trained models (Wang, et al. 2005).

Milled rice from a laboratory mill and a commercial scale mill are evaluated for head rice yield using a shaker table and a machine vision system called the Grain Check. Comparisons are made for both medium and long grain rice varieties. For each variety, samples with different levels of broken kernels are analyzed to determine the performance of the two instruments over a range of head rice yields. In that Head rice yield for laboratory milled long – and medium – grain rice is measured for samples obtained from three drying conditions using a shaker table and a Grain Check system. (Guzman and Peralta 2008)

For calculating vitreousness it does the comparison of the effectiveness of transmitted and reflected kernel images. Based on the position of kernels the quality results can differ. This deficiency should be eliminated while measuring grain quality (Wang, et al. 2005).

In grain check system vibrator is used for separating kernels. So, it cannot be used if rice kernels are connected or overlapped. Only two varieties of rice are focused. With different varieties, rice features affect differently to quality (Guzman and Peralta 2008).

2.7.3.2 Automatic grain quality inspection (Wan and Fangquan 2002)

In Automatic Grain Quality Inspection focuses on automatic grain quality inspection methods (Wan and Fangquan 2002). The article suggests the computer based system in association with grain quality inspection software. Sixteen parameters relating to rice appearance characteristics were used to categorize rice kernels into 13 inspection categories. In that study, learning mechanism is embedded into the system to increase its smartness to boost the parameters' preparing and sorting using a precision tuning. Three classifying methods namely range selection, neural network and hybrid algorithms were implemented in the inspection software. The unit is developed for sorting of rice grains into sound, cracked, chalky, immature, dead, broken, damaged and off-type categories.

The system is composed of two main parts, an inspection machine and an image-processing unit. In brief, the rice kernel handling procedure involves the following steps. First, rice kernels are scattered over a predetermined matrix positioned conveyer belt. Photograph of seeds on conveyer belt is taken by two CCD (charge-coupled device) cameras which are connected to the computer. The first camera is a Sony XC-711 color CCD camera and other is A Sony XC-75 black and white CCD cameras. The computer segregates the kernel images from the background, provides a recognition process, and transfers the final sorting results to the machine controller. The controller signals each corresponding pneumatic valve to eject the kernels from the carrying holes into collection containers. An interface protocol is developed between the inspection machine and the image-processing unit to coordinate their concurrent activity.

2.7.3.3 Many other online image based grain analysers

The research experiment "Determining wheat vitreousness using image processing and a neural network" (Wang, Dowell and Zhang 2003) brings out the real-time wheat analysis technique. It suggests an image–based grain–grading system combined with ANN classifiers to classify durum wheat vitreousness.

The research (Sun, et al. 2014) concentrated his experiential work for the evaluation and analysis of chalkiness of connected rice kernels using image processing technology and support vector machine. The study concludes that the classification accuracy for indica rice and Japonica rice reached up to 98.5% and 97.6% respectively, using SVM. The study also concludes that the measurement results are accurate and reliable for further application of computer vision technology for the chalkiness detection.

The related research work is summarized in the work of (Pan, et al. 2016) towards changes in kernel morphology and starch properties of brown rice during cooking process,(Yu, et al. 2016), (Phophalia and Mitra 2016)for image de noising using rough set and kernel PCA method, chemo metric analysis is done for monitoring the authenticity of organic rice by(Borges, et al. 2015). Experiments (Lin, et al. 2014) suggest a novel matching algorithm for splitting touching rice kernels based on conture curvature analysis. The work (Jinorose, Prachayawarakorn and Soponronnarit 2014) suggests image analysis based approach to evaluate changes in physio chemical properties during cooking of rice kernels. The important work in the image processing techniques carried out to analyze rice dimensions (Huang, et al. 2015)(Kuo, et al. 2016)(Liang, et al. 2016)(Yao, xiang Xian, et al. 2014).

2.7.4 Online Image Based Grain Analysers Limitations

In online grain analysis, the grain would be in moving condition and for capturing particular kernel image there would be very little time. So with this approach, there is a chance of missing current kernel while processing the previous kernel; which affects final quality results. With this option, faster processor and high-speed cameras are required which deals with image capture and processing part in parallel. Kernel shall be capable of handling major issues with online image-based techniques, be it reflected, transmitted or side-transmitted. Chalkiness is also not considered with studied online grain analysers, which is having much importance in quality measurement. It also requires dealing with complex issues like touching and overlapped kernels which uses rotating conveyer belt mechanism.

2.7.5 Offline / Online Image Based Grain Analyser Limitations

There are some good features which are provided by offline image based grain analyser and some good features are provided by online image based grain analysers. Table 2.1 shows the comparison of an offline and online image based grain analyser's features.

TABLE 2.1: Comparison of different grain analysers

	Seed Count 324 (Armstrong, et al. 2005)(SeedCount-Ltd. 2006)	**Image acquisition system** (Guzman and Peralta 2008)	**Rice Quality Analyser RN300** (Kett – RN300 2009)	**HRY GrainCheck310** (Wang, et al. 2005)	**Automatic grain quality inspection** (Wan and Fangquan 2002)
Offline / Online	Offline	Offline	Offline	Online	Online
Chalkiness / Vitreousness	No	No	No	No	No
Predetermined Matrix	Yes	Yes	Yes	Yes	Yes
Camera Angle Dependency	Yes	Yes	No	Yes	Yes
Light Source Dependency	Yes	Yes	Yes	Yes	Yes
Light Transmission	No	No	Yes	Yes	No
Consume more static sample preparation time	Yes	Yes	Yes	No	No
Grain should be fit in grain slot	Yes	Yes	Yes	NS*	Yes
Time	NS*	NS*	1 Sample / 24 Secs	NS*	1200 Kernels / Min
Grain	Rice	Rice	Rice	Wheat	Rice
Maximum no. of Kernels	1350	110	1148	50	24
Technologies	NS	CIAS 2.0, MS Excel, Neural Network	Quality Scan, Matlab, Neural Network	Grain check	C, Visual Basic
Vibration	No	No	No	Yes	No

NS* – Not Specified, NA* – Not Applicable

2.8 Grain Analysis Standards

This section describes importance of various standards provided by standard organisations.

2.8.1 Importance of standards

For any grain, quality is a very important factor. The food product which is made from grain is having direct relation with human health. Good quality food can be prepared from good quality grains. Therefore any progress made for grain quality measurement techniques, is directly beneficial for society. Moreover, it will also help in getting higher selling price from consumer.

It is required to define some measurement criteria for categorisation of good quality grain sample. Many organisations are working for defining standards for different kind of grains and food products. All organisations defined their own standards based on their geographical location; consumer needs, nutrition factors and other environmental parameters. Standards are defined for size, color, appearance, cooking and packaging techniques and for sampling. Based on that standardisation, sorting and categorisation is done for different types of grain samples. There is also possibility that an organisation is following more than one standard for categorisation. It might be vary with different varieties, different group of consumers and exporting norms.

Organisations provide measuring quality data that can be used for decision making in identifying better quality grains. Rice and wheat are most consumed cereal grain in India. It provides more than one fifth of the calories consumed worldwide by humans. India is ranked 1 in largest rice producing companies in the world for exporting Basamati rice(Exporters India 2017). So we have considered rice quality measurement as a base.

With this research various rice standards are studied, and based on that the techniques are developed which can be configured for meeting those rice standards. Various standards are defined by various organisations for physical feature analysis of grain is discussed next.

2.8.2 Rice standard organisations

The most commonly accepted standards for rice are provided by Bureau of Indian Standards (BIS), Directorate of Marketing & Inspection (DMI), Department of Food & Public Distribution (DFPD), ARSO (African Rice Standard Organisation), CODEX Standards, Cambodia milled rice standards and "Food and Agriculture Organisation of United Nations".

2.8.2.1 Bureau of Indian Standards (BIS)

Bureau of Indian Standards, Manak Bhavan, New Delhi, India (FAD16 10730_12092016 2016)has provided method of analysis food grain part I FAD 16 (10730) C. Standards are provided for the wheat, maize, paddy, rice, barley, gram and other pulses. The seeds refractions as other food grain, damage, discolored, insect damaged, broken and slightly damaged are considered for 20gm grains. Percentage of each category is considered as given below equation:

$$X \text{ category seed percentage} = (\text{no. of } X \text{ category seed} * 100) / \text{Total no. of seeds}$$

For wheat shape analysis the parameters are mostly used as area, parameter, compactness, major axis and minor axis length (Shouche, et al. 2001).

2.8.2.2 Directorate of Marketing & Inspection (DMI)

Directorate of Marketing & Inspection, Ministry of Agriculture and Farmers Welfare, Government of India (DMI 2016)which provides standards for all agricultural foods. It has considered CODEX 192-1995 (adopted in 1995 and revised yearly till last 2016) standard as a base for universally adoption. The Codex Alimentarius or "Food Code" is a collection of standards, guidelines and codes of practice adopted by the Codex Alimentarius Commission. The Commission, also known as CAC, is the central part of the Joint FAO (Food and Agriculture Organisation) / WHO (World Health Organisation) Food Standards Program and was established by FAO and WHO to protect consumer health and promote fair practices in food. It provides standards for different pulses, fruits, vegetables, tobacco, tea, amala, cocoa, fiber crop and all edible nuts.

It has provided *maize* standards (Agmarknet-Maize 2016)**,** which includes foreign matter (organic and inorganic), damaged grains, immature/shriveled grains, weevilled grains, other edible grains, admixture of different varieties and Moisture content in sample. Based on percentage existence of different types of grain kernel in sample the maize quality is categorised in Grade –I, II, III and IV.

It has also provided standards for *rice and wheat* (Agmark-Wheat 2016), which is based on consideration of wholesomeness, appearance, colour, foreign matter (organic and inorganic), damaged grains, broken grains, immature / shriveled grains, weevilled grains, wheat of other variety, other food grains and moisture content. Based on percentage existence of different types of grain kernel in sample the wheat quality is categorised in Grade –I, II, III and IV.

2.8.2.3 Department of Food & Public Distribution (DFPD)

Department of Food & Public Distribution, govt. of India, Krishi Bhawan, New Delhi (DFPD 2014)specifies standards for all varieties of paddy, rice, bajra, jowar, maize and ragi which includes foreign matter, damaged, discolored grains, chalky grains, red grains, admixture of lower class and moisture content percentage in grain sample For every types of grain analysis it is required to measure same kind of parameters. Common analyser can be developed which can measure all parameters, and based on percentage value of all parameters the overall sample quality can be determined. Percentage of different type of seed in the sample is described in *[ref. sec. 2.8.2.1]*.

2.8.2.4 CODEX Standards

The first recorded universal instance of food additives standardization is, CODEX STAN 192-1995, adopted in 1995 and revised yearly till last 2016 (Codex Alimentarius 2016). These grain standards and inspection procedures are designed to ensure a uniform product and to facilitate the trading and marketing of universal grain. It is universally accepted standards. With CODEX standard for rice 198-1995 (CODEX STAN 198-1995 2016) standards the grain seed is classified in mainly three categories long seed, medium seed and small seed. Classification of seeds depends on the selected option i.e. based on seed length / width ratio, based on seed length, based on a combination of the seed length and the length/width ratio.

CODEX STAN 198-1995 classifies seed based on dimension criteria as given below:

1. ***Kernel length / width ratio***: (*Long grain* – length width ratio of 3.1 or more, *medium grain* – length / width ratio 2.1-3.0, *short grain* – length /width ration 2.0 or less)

2. ***Kernel length***: (*long grain* – kernel length 6.6 or more, *medium grain* – kernel length of 6.2 mm or more but less than 6.6 mm, *short grain* – kernel length less than 6.2 mm)

3. ***Combination of kernel length and length / width aspect ratio***: (*long grain* – a kernel length of more than 6.0 mm and with a length / width ratio of more than 2 but less than 3, or; a kernel length of more than 6.0 mm and with a length/width ratio of 3 or more. *Medium grain* - kernel length of more than 5.2 mm but not more than 6.0 mm and a length/width ratio of less than 3, *Short grain* - has a kernel length of 5.2 mm or less and a length/width ratio of less than 2 mm.)

Moreover, these standards would be based on milling degree (Milled rice, under milled rice, well-milled rice and extra-well-milled rice).

It gives definitions for paddy, husked, milled, parboiled and glutinous rice. This standard defines maximum percentage of allowable other organic extraneous matter. It also specifies the contaminants, hygiene, ingredients, packaging and labeling standards for rice.

2.8.2.5 The African Organisation for Standardisation Standards (ARSO : ARS 464 (English) : Milled Rice Specification 2012)

The other recorded instance of standardization is based on African Rice Standard Organisation(ARSO : ARS 464 (English) : Milled Rice Specification 2012)CD-ARS 464: (2012(E)). ARSO divides grain seeds into head, broken and chip seed. Broken seed is further classified in long broken, medium broken and small broken.

This African standard specifies the requirements and methods of sampling and test for milled rice of the varieties grown from *Oryza spp*. intended for human consumption. ARSO standards are defined by keeping CODEX STAN 1 (CODEX STAN 198-1995 2016) as a base.

Based on ARSO (CD-ARS 464:2012(E)) (ARSO : ARS 464 (English) : Milled Rice Specification 2012) – African Rice Standard Organisation, grain seeds are divided into head, broken and chip seed. Broken seed is further classified in long broken, medium broken and small broken as shown in Fig. 2.9.

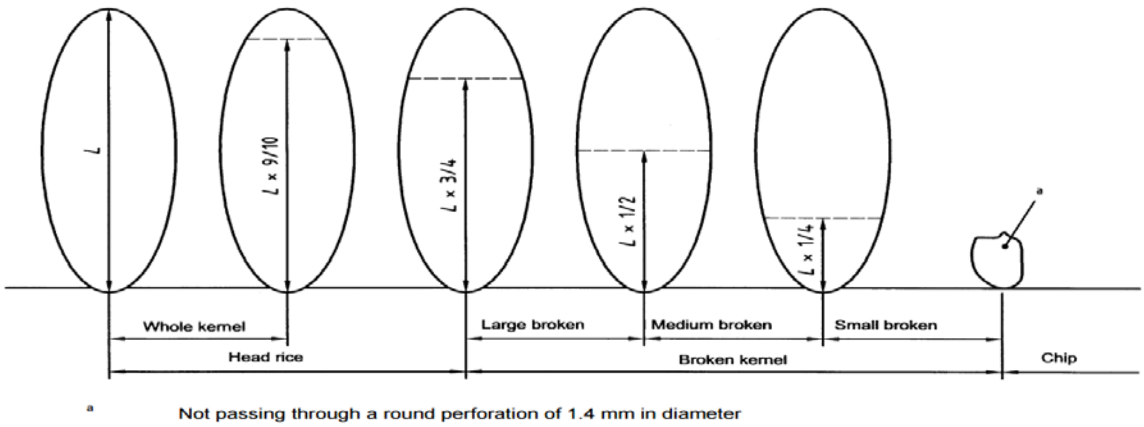


FIGURE 2.9: The African Organisation for Standardisation (ARSO : ARS 464 (English) : Milled Rice Specification 2012)

ARSO CD-ARS 464:2012 (E) classifies seed with below criteria:

1. ***Head rice*** (Length greater than LX3/4),

2. ***Whole kernel*** (length L – L X 9/10),

3. ***Broken kernel*** length L (large broken- LX3/4 – LX1/2, medium broken - LX1/2 – LX1/4, small broken – less than LX1/4).

An ARSO standard gives definitions for paddy, husked, milled, parboiled and glutinous rice. This standard provides maximum percentage of allowable other organic extraneous matter. It also defines the contaminants, hygiene, ingredients, packaging, labeling and sampling methods for rice. It also defines colored kernel i.e. immature, black, chalky, red, red-streaked, yellow and amber kernel.

Moreover, these standards could be based on milling degree (Milled rice, under milled rice, well-milled rice, and extra-well-milled rice).

2.8.2.6 Cambodia milled rice standards(CS053:2014-Rev.1)(Intenational Financial Corporation 2014)

These standards provide the definitions for paddy rice, brown rice, milled rice and germ. It provides definitions to identify whole, head, big broken, small broken and chalky kernel. It provides definition for color based categorisation such as red, red streaked and yellow kernel. Immature, damaged, foreign matter and foreign odor are also defined by this standard.

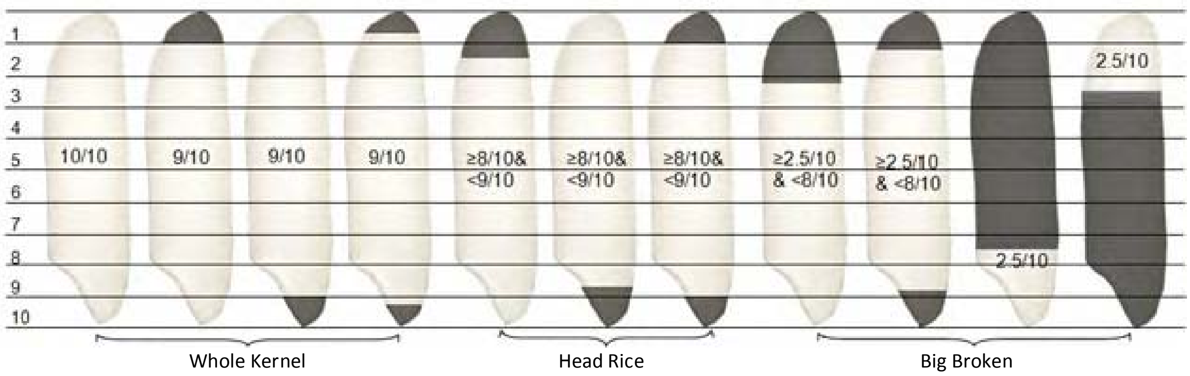


FIGURE 2.10: Cambodia milled rice (whole, head, broken) (Intenational Financial Corporation 2014)

Classification for Cambodia milled rice is as shown in Fig. 2.10. Whole kernel includes the kernel length in between 9/10 to 1. Head rice kernels are having length in between 8/10 to 9/10. Big broken should have the kernel length in between 8/10 to 2.5 / 10.

2.8.2.7 United States standards for rice by USDA (Grain Inspection Packers and Stockyards Administration 2009)

USDA (United States Department of Agriculture) has provided rice standards in 2009 (Grain Inspection Packers and Stockyards Administration 2009). It has defined broken kernels, chalky kernels and different four classes of rice for different rice varieties.

Four classes include following types of kernels:

1. ***"Long grain rough rice"*** shall consist of rough rice which contains more than 25 percent of whole kernels and which after milling to a well-milled degree, contains not more than 10 percent of whole or broken kernels of medium or short grain rice.

2. ***"Medium grain rough rice"*** shall consist of rough rice which contains more than 25 percent of whole kernels and which after milling to a well-milled degree, contains not more than 10 percent of whole or large broken kernels of long grain rice or whole kernels of short grain rice.

3. ***"Short grain rough rice"*** shall consist of rough rice which contains more than 25 percent of whole kernels and which, after milling to a well-milled degree, contains not more than 10 percent of whole or large broken kernels of long grain rice or whole kernels of medium grain rice.

It also defines mixed rough rice, damaged kernels, heat damaged kernels, milling yield, paddy kernels, red rice and smutty kernels.

2.8.2.8 Food and Agriculture Organisation of United Nations(FAO United Nations 2015)

FAO (Food and Agriculture Organisation of United Nations) has provided different standards for grading of rice.

Rice kernels are classified as per the length of the whole brown rice grain as below:

1. ***Extra-long*** - Paddy with 80% of the whole brown rice kernels having a length of 7.5 mm. or more.

2. ***Long*** - Paddy with 80% of whole brown rice kernels having a length of 6.5 mm. or more but shorter than 7.5 mm.

3. ***Medium*** - Paddy having 80% of the whole brown rice kernels with a length between 5.5 mm. to 6.5 mm.

4. ***Short***– Paddy with 80 % of the whole brown rice kernels shorter than 5.5 mm.

It also defines lb ratio, damaged kernel, yellow kernel, red rice, impurities and foreign mater.

2.8.3 Trading Market Specification Worldwide

Different standards are followed by traders, which is mainly to satisfy the market need. It becomes essential while exporting. The all quality based specifications can be measured based on appearance except aroma and milling degree. Image processing techniques is excellent solution for appearance based quality parameters.

All India Rice Exporters Association, New Delhi, India (All India Rice Exporters Association 2017) is an association of rice exporters with the prime mission of influencing export policy of rice. It includes min l/b ratio, moisture content, damaged, chalky, broken, foreign, red stripped grain, paddy, elongation ratio, and green grain. **Department of Food & Public Distribution, govt. of India** specifies standards for rice based on foreign matter, damaged, discolored grains, chalky grains, red grains, admixture of lower class and moisture content (sra-010914.pdf 2014). **KAYAVLON Impex Private Limited, Gujarat, India** (Kayavlon 2017) is ISO 9001:2008 certified millers / exporters rice in India. For different rice varieties specification includes the parameters average grain length (pre - cooked), moisture content, broken, chalky kernels, damaged / discolor and paddy / black grains and foreign matter. **Rice Authority** (Rice Authority 2016), largest Vietnam rice exporters includes broken, whole grains, moisture, color sorting, length, discolored, damaged, admixture, red streak, black, yellow, foreign matter, paddy and milling. **Vaighai** World wide’s Basamati rice specification includes length, broken, damaged, discolored, paddy, foreign matter, taste, moisture and aroma (Vaighai Worldwide 2016). For other pulses specifications, also mainly foreign matter, size, damaged and broken grains are considered (Valency International Trading Pte Ltd. 2016). **LE GROUP** considers long, broken, moisture, damaged, yellow, foreign, chalky, red and milling degree for rice specifications (LE Group Industries 2016).

2.8.4 Rice standards in Brief

Many other different rice standards are studied (US Grains Council 1988) (IRRI - Rice Knowledge Bank 2016). The conclusion of the various standards revolves around measurement of length, width, area and other physical parameters. Then after, based on single or combining one or more parameters, sorting and classifications redeveloped. Length and width of grain are critical parameters for grain samples classification.

With this research, we have implemented grain analyser which categorises the seeds based on different standards. Developed grain analyser gives selection of the different standards for the classification of grain sample. New standards can also be added to meet different organisation criteria.

2.9 Summary and Problem Formulation

Based on an extensive literature search, we found that Image processing technologies can be a vial solution for grain quality analysis. Rice and wheat are most consumed cereal grain. It provides more than one-fifth of the calories consumed worldwide by humans.

Rice is the most widely consumed as staple food in the large part of the world's human population(Kayavlon 2017) (Wenfang, Shanbai and Siming 2013). Rice is one of the leading food crops of the world and is produced in all continents. Rice is comparatively high in caloric value and rice protein has a fairly good balance of the essential amino acids. It is only one of its kinds among other cereal grains as it is completely polished grain are consumed while other grains are processed before they reach the consumers; its quality is therefore a responsive issue. Rice is an excellent source of energy, especially energy - giving carbohydrates which are used in brain performance, everyday growth repair & physical activity. Rice is low in Fat and cholesterol free. Rice is gluten free and most non-allergic of all grains. The B - Complex Vitamin in brown rice provides energy and nourishes the skin and blood vessels. So we have considered rice quality measurement as a base. India ranked 1 for largest rice producing companies in the world(Exporters India 2017).

Basmati is a variety of long, slender-grained aromatic rice which is traditionally from the Indian subcontinent. Basmati was introduced to the Middle East by Indian traders. Through cultural exchange, it remains not only an important part of various Indian/Bangladeshi/Pakistani cuisines, but now is also used extensively in Persian, Arab, and other Middle Eastern cuisines as well. India, Bangladesh, and Pakistan are the exclusive growers and exporters of this type of rice (Wikipedia 2017).

The study of above cited literature the need for a development of automatic rice sorting on its dimensional classification is observed and these needs to be addressed using image processing or other relevant techniques. Grain analyser can be developed which is non-destructive and having low installation cost. The disadvantages of offline rice kernel sorting mechanism make the technique less adaptable in industries. Of course the technique can be useful for small laboratory set up kind of experimentation but not on a large scale analysis. However all the offline image grain analysis features should be included to provide true solution.

It is observed that manual approach for sample preparation using tray is time consuming and cannot accommodate multiple varieties of grain. It requires different tray for different grains. On-line grain analysers also have limitations related to camera resolution, camera angle, light intensity, and other environmental variability. It is also observed that the software tools available with such analysers can be used at one location and data cannot be communicated at remote location and analyzed. It is also difficult to accommodate various types of grains, and different standards available. Scalability of the software in terms of accommodating different grain, and standards at later stage is major concern.

Considering the above issues the proposed research is aimed developing image based approach to develop technology for grain analysis with following features –

1. Non-destructive automatic sampling in which tray preparation or sample pre-preparation is not required

2. Accommodate various types of grain

3. The software must support local and remote analysis, must scalable in terms of adding different grains and standards at later stage.

4. Must have accuracy same or better than the present technology

5. Foreign particles must be detected and reported

To research will be confined to the availability of various types of rice variants available in the geography.

CHAPTER – 3

Experimental Setup and Architecture

After studying grain analysis techniques discussed in previous chapter, we proposed a new grain analysis solution where efforts are made to fill gap by eliminating deficiency in conventional techniques. This technique provides novel idea of scanning technique by which sample preparation step is eliminated. Many features of both online and offline image based grain analyser techniques are combined. Subsequent sections of this chapter provide an insight to solution framework, pros and cons related to proposed solutions.

3.1 Solution Framework

We have carried out different experiments with the framework depicted in Fig. 3.1. With provided solution, grain sample is gently spread over the flat seed scanner / conveyer belt and image is captured. Captured image is then sent to processor for further processing. The features are extracted for quality measurement based on different grain varieties. All kernels are classified based on extracted features and overall sample quality is determined. We have used seed scanner option for capturing image.

3.1.1 Why Not Grain Tray

With conventional grain analysis techniques, it is required to fit grain in particular grid structure by spreading grain sample on grain tray *[ref. sec. 2.7]*. The grain tray consists of different slots (horizontally and vertically). Each slot can accommodate single seed and has predefined mapping address.This mapping addressis used by imaging software while analysis of that particular seed. Therefore it is mandate that each slot must contain at most one seed before capturing the image. Because of that it is required to pass through tedious process of separating out all kernels manually, as many slots may contains more than one seed while spreading grain sample on grain tray.

With this research novel idea is provided for scanning grain sample. Flat scanner is used for scanning which is different as compared to all conventional grain analysis techniques. With this proposed solution there is no need to arrange seed in particular manner, which overcomes the conventional analysis technique's limitations. The other advantage with this architecture, the same grain scanner can be used for analysis of different types of grain. While if predefined grid structure is used then it can be useful for only one particular type of grain variety. If grain is changed then it is also required to change grain tray, as all grains have different length width. Moreover if grain variety is changed then also it is required to change grain tray. So it is very difficult to manage many number of grain trays with conventional techniques. Enough time can be given for capturing image so there is no chance of missing any single kernel, which provides the solution for online grain analysis techniques.

The scanning surface doesn't contain any slots for accommodating grain kernels. Therefore it is require to gently spreading of grain over surface only, no need to arrange them after spreading. While spreading grain sample, there is chance of touching and overlapped kernels. To deal with that the vibrator can be used for separating out overlapped kernels. Conveyer belt with vibrator mechanism *[ref. 3.2.1.2]* can be used while capturing the grain image. However, touching kernels might be found even after the vibration. Because of that, we have developed the image processing algorithms which are powerful enough to deal with the touching and overlapped kernels.

3.1.2 Surface / Background Color

Selection of background color depends on the presence of different colorsin the grain sample elements. Back-ground color should be powerful enough to distinguish it from actual elements in the sample. With different experiments for background color, we found that blue colored background is providing best results. The main reason behind that, there is very little chance of blue color element present in grain sample. However, with different grain type and grain varieties tray background color can be changed.

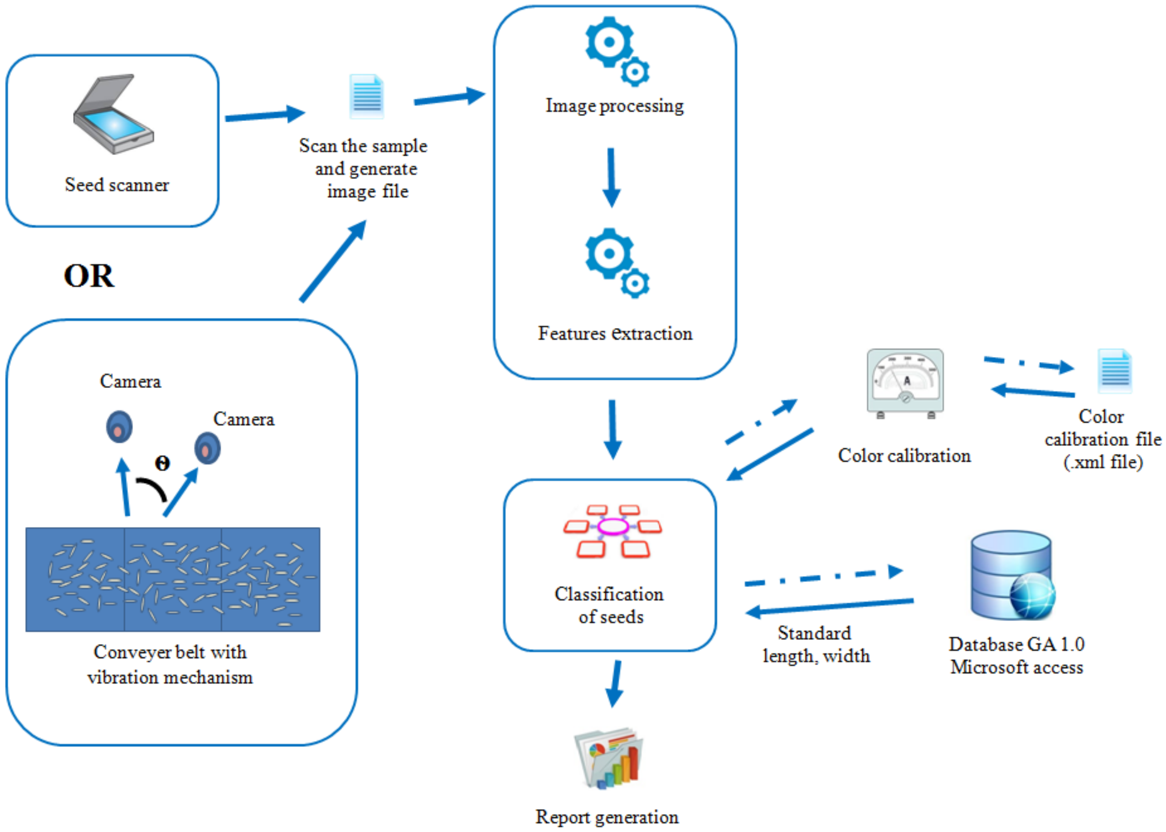


FIGURE 3.1: Solution Framework

3.2 Architecture Components

The main components of the architecture are as given below:

1. Image scanning
2. Image processing
3. Feature extraction
4. Color calibration
5. Seeds classification
6. Report generation

3.2.1 Image Scanning

Grain sample can be scanned either by seed scanner or conveyer belt mechanism techniques. Scanned image is then sent to processor for feature extraction. For experiment, scanner is used for scanning and capturing the grain sample image, same can be extended for on-line grain analysis using conveyor belt.

3.2.1.1 Seed Scanner

Seed scanner is the very important hardware component of the architecture. Grain sample is gently spread over scanner and then image is captured using scanner. We have carried out experiments with three different scanners:

1. HP Scanjet 2400
2. CanoScanLide 20
3. CanoScanLide 110

The generated results were uniform for all different types of scanners. We have tried with different resolutions of images i.e. 75 dpi, 100 dpi, 150 dpi, 200 dpi, 300 dpi, 400 dpi and 600 dpi. We have noticed that the accurate and consistent results are generated with resolution of 300 dpi images.

We have carried out our all experiments by scanning imageusing seed scanner.

3.2.1.2 Conveyer Belt

Static grain tray can provide one image of sample at a time and for next iteration it is require to cleaning it. So when huge amount of sample is there, the time would be wasted in creating next iteration setup. To resolve that, the static grain tray can be replaced by sensor based moving conveyer belt (Fig.3.2). Conveyer belt has sensor point which is useful for controlling the movement of conveyer belt. When sensor point comes, the conveyer belt is stopped and image is captured using camera. Again conveyer belt move still next sensor point. This process is repeated until whole sample is passed through conveyer belt. Captured image needs be sent to processor for further processing. Same grain analyser technique can be used by providing multiple images in a row as an input to grain analyser.

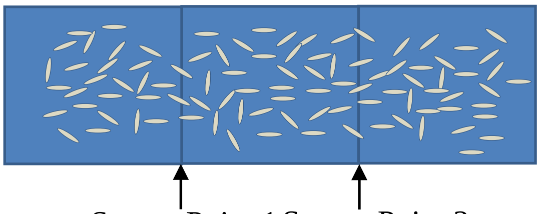


FIGURE 3.2:Conveyer Belt

3.2.2 Image Processing and Features Extraction

Captured image is filtered based on different filters. After that object map is built, with that the individual seeds blobs are created. The individual kernel features are mapped for those blobs and arrays is created. Array contains information about all individual seed available in sample with particular unique id. The generated array will be useful for classification of seed in subsequent steps.

3.2.3 Color Calibration

For color based classification, it is required to generate calibration file first. Some samples are analysed and based on identified RGB combinations the calibration file is generated. For different varieties of rice, different calibration files needs to be generated. Generation of calibration file is one time process. Same calibration file can be used as an input for same kind of rice variety. Those calibration files will be useful for identifying different colored seeds and adulteration. Calibration files can be updated whenever required for better results.

3.2.4 Seeds Classification

Developed grain analyser provides size and color based classification. For size classification, it measures length and width parameter of every grain seeds. Then classification is made based on defined organisation standards. It gives classification as whole, head, big, medium and small seeds. With selection of different organisation standard, the classification results are changed. For color classification, it identifies red, green, black, yellow, brown, paddy and white color seeds. Classification is also provided for broken and overlapped kernel.

3.2.5 Report Generation

It is very difficult to analyse the sample based on text data, so that graphical analysis is also provided. Different bar charts provides the length and width distributions among the sample. It also shows the bar chart for distribution of aspect ratio among grain sample. Size measurement pie charts are provided according to organisation criteria. Color classification pie charts are generated to identify color group detail in grain sample. All different pie charts show the % distribution of particular group classification in sample.

3.3 Issues Resolved by Proposed Architecture

Following issues can be resolved with this proposed architecture:

1. No need to arrange seed in particular manner
2. Sample preparation time is reduced
3. No chance of kernel missing as it is with online image base grain analyser
4. More number of rice samples can be analysed using same imaging setup
5. More image based quality parameters can be added like chalkiness of rice
6. Classification mechanism based on measurement standards is provided
7. Different types of grain varieties can be analysed without changing imaging setup
8. Different types of grain can be analysed without changing imaging setup

3.4 Emerged Issues with Proposed Architecture

Following issues are emerged with this proposed architecture:

1. Identification of touching kernel which are not separated by vibration
2. Identification of overlapped kernel which are not separated by vibration
3. Identification of each kernel’s individual address as there is no direct mapping for that
4. Position of kernel which might be vertical, horizontal or angular

5. Combinations and analysis of each iteration outcomes

6. Boundary seed kernel appears in more than one iteration

So by providing all the said featured in one solution, many conventional grain analysis techniques' deficiencies can be removed and intelligent grain analyser can be developed to enhance speed and accuracy.

3.5 Summary

With this solution there is no need to arrange seed in particular manner, which overcome the main offline analysis technique's limitations. There is no chance of missing any single kernel, which provides the solution for online grain analysis techniques. With this approach, different rice varieties can be analyzed using same imaging setup. Traditional techniques measure only four parameters length, width, thickness, and roundness. With this solution, more quality parameters can be measured which can accommodate measurement quality by considering dimensional approach, like chalkiness of rice.

Chalkiness (Guangrong 2011) of rice is one of the important factors for measuring rice quality. Milling rice can be brittle if more chalkiness is there. While exporting rice it has great significance and must be added into quality measurement part. Sorting can be more robust with chalkiness information. With developed grain anlayser facility is provided for measuring the chalkiness of rice.

The only limitation to address is, if the camera angles are changed then how it will affect to quality is not addressed with this research. Moreover light intensity is considered static. With change in light source image clarity would be changed, which leads to different quality results. These are research gaps associated with conventional techniques which should be overcome. Weight of seed has direct mapping with quality parameters which is not considered with this conventional techniques. As weight also affects the quality, efforts should be made to map seed weight with based quality parameters.

With this research, color seed can be analysed like red, green, black, yellow, brown, paddy and white color seeds. It gives information regarding the whole, head, big, medium and small seeds. It provides the detail regarding total number of overlapped and broken seeds. It also provides information regarding chalkiness of the seed. Average parameters such as length, width, area, aspect ratio, chalkiness can be determined with this technique.

The important feature of developed grain analysers it provides the detail of individual seed.We can select particular seed in sample image itself and get the details of that seed individually. For individual seeds, it gives facility to measure length, width, area, aspect ratio, color set, exact color, color group name and type of seed. We can also able to identify the particular seed is broken or not. Overlapped seeds are also classified using this approach.

CHAPTER – 4

Size and Chalkiness Measurement

The importance of size and color is the primitive consideration in determining the economic value of any grain. Price of the item depends on appearance of final product. The length and width of a rice grain are important attributes that determine the class of the rice.

Appearance is the first parameter of consideration for quality by consumers. Consumer acceptance of grain and food highly depends upon the appearance. Appearance affects the quality of the grain. Wide research is going on for color and size measurement of the grain. Image analysis has proven effective solution for measuring grain quality.

Length and width of grain are critical parameters for grain samples classification from top level as short grain, medium grain and long grain.

Chalkiness one of the important factor for milling rice is measured. It also provides facility of providing area of individual seed, which can be useful for identifying fullness of seed. A chalky grain is the having at least 50% of milky white color and that seed is brittle as compare to other regular seed.

4.1 Size Measurement Algorithm

Summaries, the classification can be done based on the measured length and width of the seed. But size difference is measured for the below scenarios:

1. Same sample analysed again with different resolution (without changing seed position).
2. Same sample analysed again with same resolution but with seed position changed

Size variation is because of the resolution of the image and angle of the grain seed. So size of rice required to be calibrated. The simple calibration can be done as given below for the first mentioned scenario.

Size of grain = Software measured size of grain +/- Deviation

But this formula doesn't work while experiment is made for the second scenario. The reason behind that is, the size variation also depends on the angle of the seed position with reference to tray edges. If all the seeds are placed with same angle then the discussed formula can be applied. The angle based size measurement algorithm (AForge Imaging Library 2017) is as given below:

1. Find the angle between points P1(x1, x2) and P2 (y1, y2) based on dy (y1-y2) and dx (x1-x2).
2. Find the radiant angle by (-angle * pi /180) and based on that find the sine angle (sa) and cosine angle (ca).
3. Get the half width (hw) and half height (hh) of image.
4. Rotate corners of four points (cx1, cy1), (cx2, cy2), (cx3, cy3) and (cx4, cy4) using below equation:

    1. cx1 = hw * ca;
    2. cy1 = hw * sa;
    3. cx2 = hw * ca - hh * sa;
    4. cy2 = hw * sa + hh * ca;
    5. cx3 = -hh * sa;
    6. cy3 = hh * ca;
    7. cx4 = 0;
    8. cy4 = 0;

5. Re-Calculate half width and half height as below:

    1. hw = Max(Max(cx1, cx2), Max(cx3, cx4)) - Min(Min(cx1, cx2), Min(cx3, cx4));
    2. hh = Max(Max(cy1, cy2), Max(cy3, cy4)) - Min(Min(cy1, cy2), Min(cy3, cy4));

6. Return original size by doubling height and width.

As summaries, the classification can be done based on the measured length and width of the seed. But size difference is measured for the below scenarios:

1. Same sample analysed again with different resolution (without changing seed position).
2. Same sample analysed again with same resolution but with changing seed position

Size variation is because of the resolution of the image and angle of the grain seed. So size of rice required to be calibrated. The simple calibration can be done as given below for the first scenario.

Size of grain = Software measured size of grain +/- Deviation

But this formula doesn't work while experiment is made for the second scenario. The reason behind that the size variation is also depends on the angle of the seed position with tray boundary. If all the seeds are placed with same angle then the discussed formula can be applied. The angle based size measurement algorithm is as given below:

7. Find the angle between points P1(x1, x2) and P2 (y1, y2) based on dy (y1-y2) and dx (x1-x2).

8. Find the radiant angle by (-angle * pi /180) and based on that find the sine angle (sa) and cosine angle (ca).

9. Get the half width (hw) and half height (hh) of image.

10. Rotate corners of four points (cx1, cy1), (cx2, cy2), (cx3, cy3) and (cx4, cy4) using below equation:

    1. cx1 = hw * ca;
    2. cy1 = hw * sa;
    3. cx2 = hw * ca - hh * sa;
    4. cy2 = hw * sa + hh * ca;
    5. cx3 = -hh * sa;
    6. cy3 = hh * ca;
    7. cx4 = 0;
    8. cy4 = 0;

11. Re-Calculate half width and half height as below:

    1. hw = Max(Max(cx1, cx2), Max(cx3, cx4)) - Min(Min(cx1, cx2), Min(cx3, cx4));
    2. hh = Max(Max(cy1, cy2), Max(cy3, cy4)) - Min(Min(cy1, cy2), Min(cy3, cy4));

12. Return original size by doubling height and width.

4.2 Chalkiness Measurement Algorithm

Chalkiness can be identified by image processing techniques. It is required to find milky color percentage in seed. Based on the percentage value the seed can be categorised either as chalky seed or normal seed.

With following steps we measured the chalkiness:

1. Select the image
2. Identify all the blobs in the images
3. For each seed repeat the step 4 to 13
4. Apply the base filter
5. Convert image to gray scale image with r, g, b filter value as 0.2125, 0.7154, 0.0721.
6. Convert remaining image as RGB colored image to subtract it
7. Repeat the step 8 to 11 for each pixels in the seed image
8. Check if (r,g,b) value is not (0,0,0) then repeat step 9,10 else goto 11.
9. Increment T value by 1
10. If pixel comes under chalky threshold then increment CH by 1.
11. Get next available pixel in the seed image
12. Calculate total no of chalk pixel percentage in the seed (chalk = CH/T).
13. Get next seed in the image
14. Display chalk percentage for all the seeds.

4.3 Summary

Based on discussed algorithm size and chalkiness are measured. It is required to calculate average quality parameters length, width and chalkiness for the rice sample. Facility is provided for getting individual seeds details as well.

CHAPTER – 5

Color Calibration

5.1 Introduction

Colors are the first parameters of consideration for quality by consumers. Color is also important for breeding of cereal varieties as it affects the quality and appeal of processed grain, and is also associated with dormancy in multiple species. Consumer acceptance of grain and food highly depends upon the appearance. Appearance also affects the quality of the grain. Wide research is going on for color and size measurement of the grain. Image analysis has proven effective solution for measuring grain quality. Though tedious, but it is very important to do the color based qualitative analysis of the individual seed.

Color is very important for accepting or rejecting any food. Different color cereals have different quality parameters associated with it. The food product produce from different colored cereals have different color and different taste.

5.2 Why it is important?

Color calibration is important as all organisation following different measurement standards and have different color batch/category name. Same seed can be classified into different color group with the different organisation standards. For example, red colored seed might be classified in light red or pink colored seed by other organisation. To deal with that generalised grain analyser should be developed, which has customisation mechanism.

5.3 Conventional Techniques

For capturing colored image different instruments like cameras, scanners are considered with varieties of hardware configurations. Because of that it is required to develop algorithms which can identify and measures the same graphical elements taken with different instruments. Different graphical techniques required for the scenes are taken with different lightning conditions (Porikli 2004) (Sabri Gurbuz 2010). Different 3D viewpoints are analysed taken with either same or different instruments/environment conditions (Kun Li 2010). Color calibrations are also useful for the true-color LED to enhance the performance of true-color image display (Katherine Leon 2006) (Shih-Mim Liu 2014). Temperature, lightning conditions and different instruments manufacturing process lead to different results for the displays. It results in visual fatigue and low quality of color perception (M. Ogata 2005).

In summary, image processing algorithms are made in such a way that the different colored pixels are categorised in same group by some correlation, histogram or other mapping functions. It is require because any captured image of same thing may have different combinations of RGB pixel values, if it is taken with different instruments or different lightning conditions. Those RGB combinations must be then correlated to generate consistent results using image processing algorithms. With conventional techniques the attempt is mostly made to provide different input images (images of same thing with different environment conditions) to same imaging software and produce consistent output using static imaging algorithms. Thus, calibration made at image processing algorithm level doesn't help when the environment variables or lightning conditions are changed after the development of imaging software.

5.4 Developed Grain Analyser's Algorithms

With this research instead of providing calibration at image processing algorithm level, the calibration is provided at user level. Efforts are not made for correlating of original pixel color by image processing techniques, instead of that original pixel colors are identified and mechanism is provided to calibrate that pixel color by user itself.

It provides the way to identify the same seed with different color name according to different organisation standards. With this mechanism any seed can be classified in particular color batch/category in line with organisaiton customisation. The calibration is done after feature extraction instead of doing at intermediate level. Mechanism is provided to calibrate final output according to organisation standards.

Images of grain sample are captured and configuration files are generated. Generated configuration files acts as an input while actual grain quality analysis is made. Machine learning mechanism is used for generating trained data as configuration file.

Color calibration is required for the analysis of colored image and to generate results from them. For color calibration at granule level, it is require measuring the pixel color. Any individual pixel in image have the RGB combinations value based on that pixel color is identified. To get any seed color it is require to find maximum number of the same RGB combinations pixels in that particular seed. That RGB combination acts as color value for the seed. Imaging algorithm first decides the RGB combinations and provides the seed color name. That seed color name might be changed when it is processed using configuration files.

As discussed earlier, all organisations have their own identification mechanism for colored grain seeds. Same set of color range have different implications base on organisations internal criteria. Calibration method should be provided to mark these RGB combinations according to organisation standards. If we consider all the real possible RGB combinations for naming, then it is mostly impossible to classify them all and moreover they don't fall under the domain range. There is requirement of identifying the interested RGB combinations for that. Only these combinations need to be considered for the analysis process. To identify this kind of interested RGB combinations, two approaches are considered (discussed in subsequent paragraphs).

Color analysis is required for the analysis of colored image and to generate results from them. For color calibration at granule level, it is required to measure the pixel color. Any individual pixel in the image have the RGB combinations value based on that pixel color is identified. Next, with grain sample analysis, to identify the seed color it is required to find maximum number of pixels with the same RGB combinations in the seed. That RGB combination acts as color value for the seed.

Classification of seed type (color) would be done based on input calibration file. Calibration file is generated by analysing training data set. Calibration file consists of different color ranges which were available in training data set. Calibration file is generated for providing trained data to analyser. Calibration file contains the detail of predefined color sets range for different kind of colored seed. Calibration file can be modified in future also, if any update is require for any color change by organisation. Modification in color file doesn't affect the actual algorithm implementation. Based on calibration file and predefined standards rice seed type is classified in particular category. In case of unavailability of configuration file the predefined color calibration take place.

With this method, interested color combinations' ranges are found using few samples. These color combinations are considered as a base and named according to organisation choice.

5.4.1 Approach I

While discussing at granule level, imaging software measures the individual pixel color. It identifies maximum no. of color pixel with same RGB combination in grain sample and provides that RGB combination color as seed color. For calibration utility, method can be provided for customising this group color name according organisation choice. All different possibilities of RGB combinations (in the scanned grain sample) are identified by the imaging software. Then, facility is provided to user for configuring and naming each RGB combinations. Based on the user choice, configuration file is generated. Calibration file contains RGB combinations values and associated color group name with it. Complete workflow is depicted in Fig. 5.1.

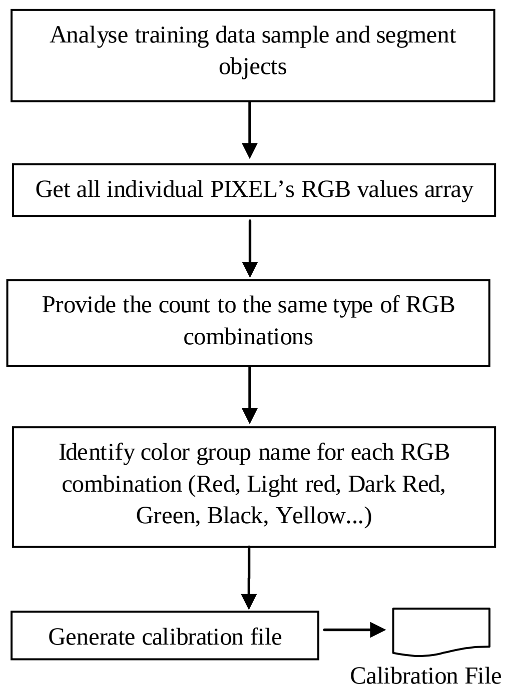


FIGURE 5.1: Color calibration with individual pixel

It also gives the information about the total numbers of pixels of particular RGB combinations while configuring, which helps in deciding the importance of it.

Generated configuration file acts as an input data for analysing grain sample. Seed color is named based on RGB combinations mapping in configuration file. Workflow is depicted in Fig. 5.2.

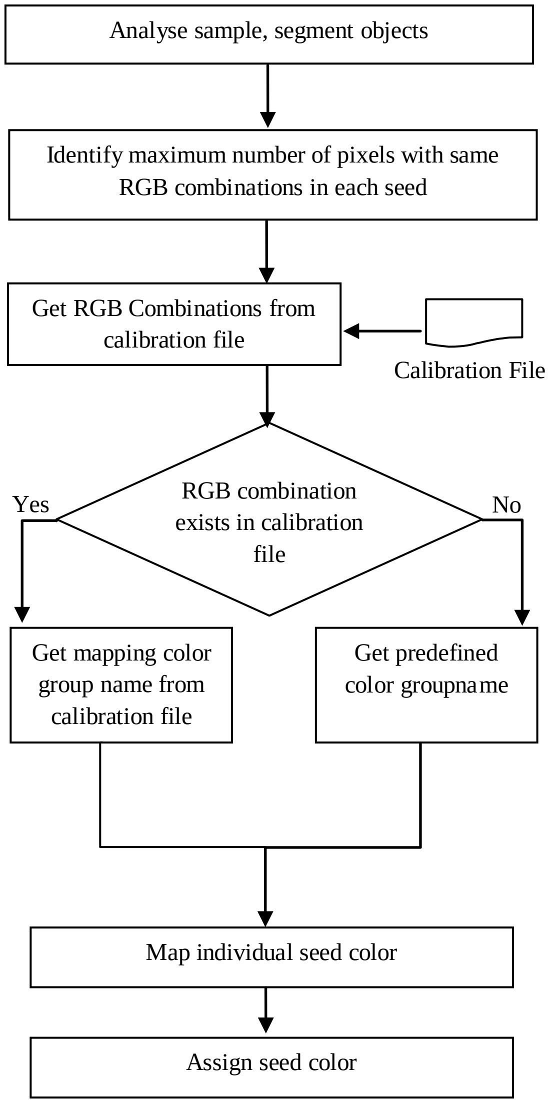


FIGURE 5.2: Color calibration with individual pixel

It is still required to provide predefined color category, as all seed color doesn't fall under predefined customised color range and remain uncategorised. For predefined color category; range can be given instead of exact RGB combinations. The reason for providing range instead of exact mapping is to cover wide spectrum of possible RGB combinations. Range combination is as given below:

Group 1:

minR1<actualRValue<maxR1; minG1<actualGValue<maxG1; minB1<actualBValue<maxB1;

Group 2:

minR2<actualRValue<maxR2; minG2<actualGValue<maxG2; minB2<actualBValue<maxB2;

…..

………

Group N:

minRN<actualRValue<maxRN; minGN<actualGValue<maxGN; minBN<actualBValue<maxBN;

5.4.2 Approach II

With *approach I,* the issue is wide range of different RGB combinations required to be calibrated. The reason behind that is the hundreds of different RGB combinations are found even when single seed image is captured and analysed. Out of them, there are many RGB combinations which are very nearer in look and have not significant different while seeing it with necked eyes. It is also not requiring to provide each combinations name, as we are not interested in individual pixel color rather we are interested in seed color as a whole. So instead of considering each RGB combination group color name we can narrow down our selection. Instead of identifying each RGB combination group color, first find the maximum numbers of RGB combinations available in single seed. Repeat this exercise for all seeds and get maximum numbers of RGB color combinations for every seeds and prepare array of it. Remove duplicate records from this array. Duplication could exist because of same color's seeds present in the sample. In *approach 1* the 2^{nd} step (see Fig. 5.1) for getting all individual pixels' RGB values array can be replaced by the getting individual seeds max RGB color combination as shown in workflow Fig. 5.3(2^{nd} step highlighted in gray color).

With *approach II,* the only change is calibration file generation method. The generated calibrated file can be used as same way as uses with *approach I* (Fig. 5.2).

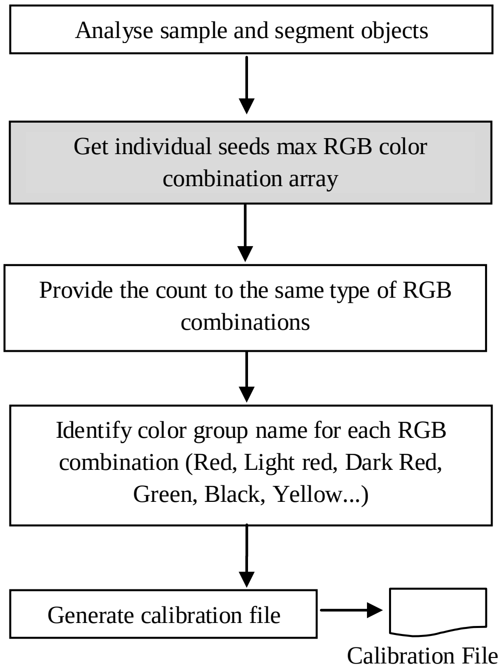


FIGURE 5.1: Color calibration with individual pixel

5.4.3 Comparisons of Both Approaches

Approach I requires many more numbers of RGB combinations to be calibrated while for *Approach II* very less numbers of RGB combinations require to be calibrated. *Approach I* gives accurate results but very time consuming, while *Approach II* can be worked out with minimal time.

CHAPTER – 6

Foreign Element Identification

6.1 Introduction

For all commodity crops quality is very important factor. For any crop it is required to do quality analysis for sorting good products (Guzman and Peralta 2008) (Raj, Swaminarayan and ISTAR 2015). While analysis of any grain sample it is required to identify non-quality elements. If non-quality elements are presents in grain then products made from it will be low in price and might be dangerous to health. However it is tedious, but it is very important to perform the individual kernel's qualitative analysis for finding non family substance in grain sample. Analyzing the grain sample manually is more time consuming and complicated process, and there are high chances of errors with subjectivity of human perception (Ramya, et al. 2010). To get uniform standard precision quality, machine based techniques are having great significance. With that we can reproduce the same qualitative result efficiency again and again. Authentication of grain sample is also done using advanced biology-based techniques focusing on DNA as the target analysis element. Image processing techniques has proven solution for many problems, the reason being with this approach mainly actual product be intact (Dutta, et al. 2016)(Kuo, et al. 2016). Current research in the field of image processing has opened up wide scope of its use for sample analysis too.

In this research, an attempt is made to investigate techniques used for the grain quality analysis. The main attempt is made to investigate foreign particles in grain sample. A foreign particle is any element exists in grain sample which is not of interest. It might be piece of stone, leaf, send; it might be the seed itself but which is not having predefined quality (i.e. immature or damaged). Non-destructive image based grain analysis technique is used for recognizing non-quality elements from grain sample. We have found different image processing approaches for identification of foreign element and made comparisons of them. Also in this research, an attempt is made to summarize the existing methods of adulteration detection and case study is provided for measuring rice (Oryza sativa L) quality with Basmati rice.

6.2 Importance of Foreign Element Identification

Grain quality is important for human beings as it affects health and development of human body. For that it is required to get good quality food products. Price of any food products is based on its quality. Quality depends on the non-quality substance presence in sample.

To get better quality grains it is required to do the quality analysis of grain samples. Analysis is done based on image analysis (Yadav and Jindal 2001) so that material is not deformed while analysis and same sample can be used for repetitive measurement of qualitative analysis.

Main tag is to distinguish non-quality elements from grain sample (Casazza, et al. 2012). Based on adulteration percentage any grain samples price is determined. For that, image analysis is done on rice sample's image. Different kinds of approaches are applied to sample analysis, based on RGB combinations mapping theory. With all approaches it is required to do machine learning. With machine learning RGB combinations values are saved as input data for identifying any foreign element in grain sample.

With this work, we tried to identify foreign element based on RGB combination value. All organisations have their own identification mechanism for foreign elements. Same set of foreign elements have different importance based on organisations internal criteria. So instead of providing one fix identification technique, we can provide some organisation dependent measurement techniques which can be configured with user's choice. Two approaches are used for generating machine learning data. While measuring actual grain sample we provided two different techniques.

6.3 Related Work

Different techniques are studied to get the idea of identifying the adulteration in crop. Quantitative real time PCR assay approach is suggested for wheat adulteration (Carloni, et al. 2016). It has also demonstrated that a 24 previously published method for the detection of T.

aestivum, based on the gliadin gene, is 25 inadequate. For rice adulteration, a detection technique is suggested by using two different rice varieties.

Research is carried out for identifying adulteration in wheat using NIR (Near Infrared Technology) spectroscopy (Cocchi, et al. 2006) (Bellon, Vigneau and Sacvila, Infrared and near-infrared technology for the food industry and agricultural uses: on-line applications 1994) (Lohumi, et al. 2015).Ultrasound techniques are used for food quality analysis (Awad, et al. 2012). A chemomatric analysis technique is another solution for authenticity of organic rice (Borges, et al. 2015). This all techniques deform the actual sample, which might not be useful to analyse again.

Image analysis has great significance in grain quality analysis. Sorting and classification can be done using different analysis techniques (Mahajan and Kaur n.d.) (Patil, Malemath and Kaur 2015) (Hobson, Carter and Yan, Characterisation and identification of rice grains through digital image analysis 2007). Different machine vision techniques are using image processing in backend to do quality analysis of rice sample (Agustin and Oh 2009)(Armstrong, et al. 2005). Color calibration is also useful in chalkiness identification of rice (Yoshioka, et al. 2007).

Foreign element identification can be done based on color. For color measurement the different configurations instruments like cameras, scanners are considered. Calibration is needed for the scenes are taken with different lightning conditions. Techniques are studied for inter camera color calibration (F. 2004). Multi-camera color calibration which capture the same scene with different angle is also useful for 3D image based examining (Kun Li 2010) (Sabri Gurbuz 2010). Instead of camera, scanner can be better option for capturing grain sample image (Muhammad A. Shahin 2003). For every measurement it is require to do color calibration for getting better quality results (Shih-Mim Liu 2014). Camera and scanners are changing so static method of measurement doesn’t work appropriately. Review is presented (Lohumi, et al. 2015) which shows spectrographic techniques for the detection of food authenticity and adulteration.

6.4 Process Workflow

Calibration techniques for foreign element identification are important as all organisations following different measurement standards and having different foreign substance identification code. Same foreign element can be classified into different group with the different organisation standards. Efforts are not made at any stage of image processing, for changing original pixel color to get desired output. Instead of that the categorization techniques are provided based on predefined criteria. For that it is required to do machine learning, based on grain variety. To make generalised grain analyser, customizable mechanism should be developed. With this mechanism any non quality element as well as actual seed should be classified in particular color batch/category according to organisation provided standards.

Developed grain anlayser analysis can be classified in two important steps:

Step 1: Machine learning

Step 2: Actual sample analysis

6.3.1 Machine Learning

The algorithmic steps are:

1. Put only foreign elements in imaging setup and capture the image.
2. Process the image and identify blobs in grain image (blob would be foreign element).
3. Identify RGB combinations in each blob of existing sample.
4. Classify all RGB combinations in particular group and provide group name according to organisation standards.
5. Generate xml configuration file.

6.3.2 Actual Sample Analysis

The algorithmic steps are:

1. Put rice seeds with adulteration in imaging setup and capture the image.
2. Process the image and identify blobs in grain image. (With this the blob can be either non-quality/foreign element or actual seed).
3. Identify the RGB combinations in each blob of existing sample.

4. Get the standard input data from xml configuration file (generated with step 1of machine learning algorithm).

5. Categorise the blob's RGB combination according to xml file and put it into particular group.

Machine learning algorithm is first subtracts the background and identifies elements in the sample. Each elements map with blob, which has particular id associated with it. Different approaches are used for developing machine learning mechanism (Fig. 6.1). Either of below two approaches can be followed for that mechanism, discussed subsequently.

6.5 Approach 1

Internally, imaging software measures the individual pixel color. All extracted blob have any numbers of pixels having diffident RGB combination. So it is required to identify that all RGB combinations and categories them all by providing group name to it. That categorization may vary with different kind of rice varieties and with different organisation standards. We have provided mechanism for grouping different RGB combinations and name it according to user's choice. It also gives the information regarding how many numbers of pixels are having same RGB combinations, which helps in deciding the importance of that RGB value combination. That name will act as category for foreign elements while actual sample measurement. Generated xml configuration files act as input data for step-2. Xml configuration files stores information regarding RGB combinations and associated group name. For different verities of rice different configuration files can be generated by repeating step-1.

In step-2 (Fig. 6.2), actual sample is analysed by providing xml file as input file which is generated in step-1. While analysis, if the identified RGB combination is already categorized in step-1 then that particular foreign element is assigned predefined associated group name. But there is chance of some RGB combinations do not appear while machine learning in step 1. That kind of combinations is required to provide static predefined range. If static range is not provided then there is chance of missing categorisation part for few foreign elements.

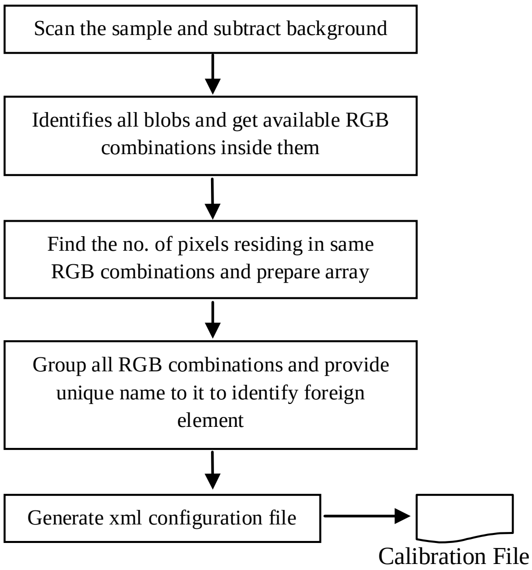


FIGURE 6.2: Machine learning for foreign elements (Step-1)

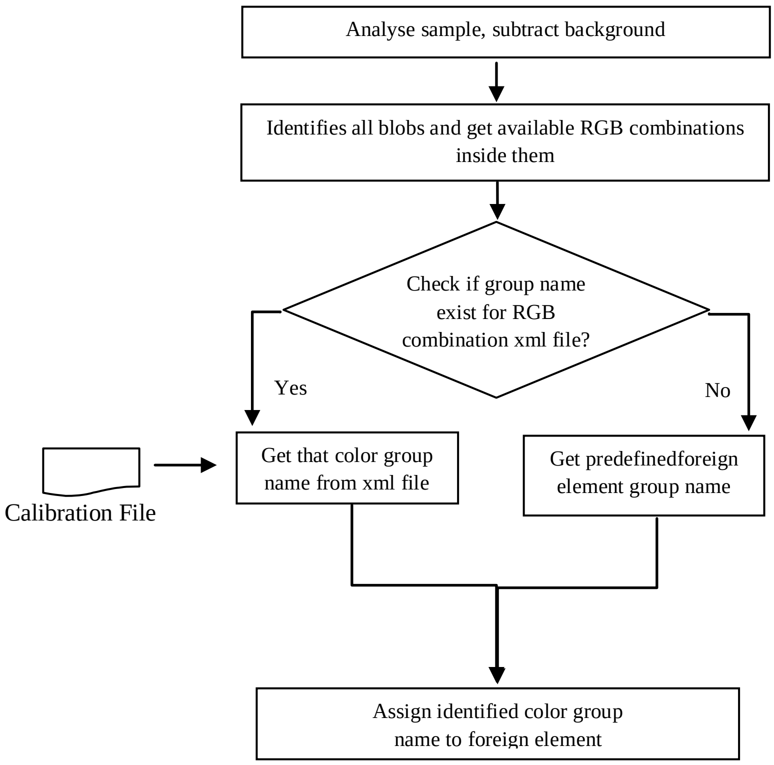


FIGURE 6.3: Analysis of actual sample (Step-2)

6.6 Approach 2

With previous approach (approach 1), the issue is the wide range of RGB combinations are generated with step-1. Out of them, there are many RGB combinations which are having similar kind of visual and have not significant difference while seeing it with necked eyes.

We can modify step 1, by changing the way of preparing RGB combination array. There is no requirement of providing group name to each RGB combinations, as we are not interested in individual pixel color rather we are interested in seed color as a whole.

With this approach, instead of providing group name to each and every RGB combinations selection can be narrow down. For that, first find the maximum numbers of available RGB combinations in particular segmented blob. Repeat this exercise for all the blobs which are identified by image processing. Next, get particular RGB combinations having maximum numbers of occurrences in particular blob and prepare its array. Remove duplicate records from this array. Now only categorise those RGB combinations to generate xml file (Fig. 6.3).

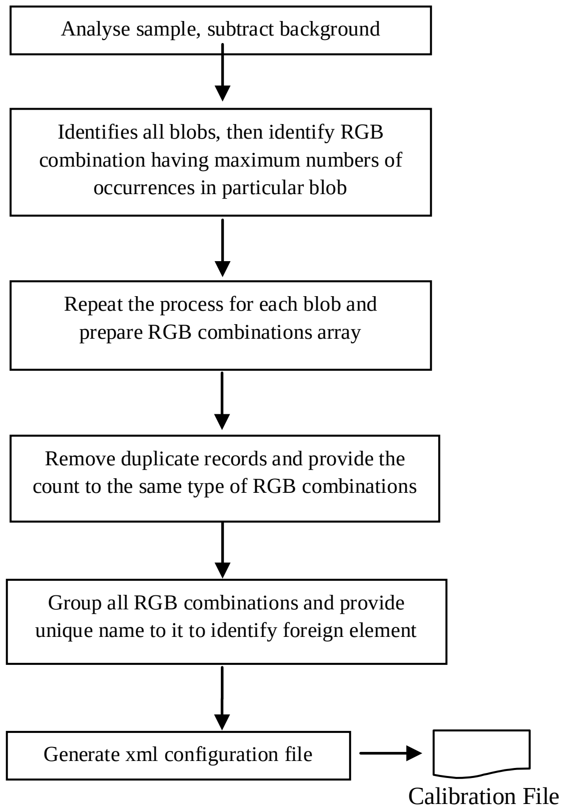


FIGURE 6.4: Color calibration with individual pixel

With approach 1, many number of RGB combinations appear in the generated array which requires to be configured to generate xml file. While with approach 2, as we are considering only the maximum number of RGB combination appearing in each blob, the number of such combination significantly reduced. With experiment we found that it is reduced up to more than 70%. However it depends on the number of elements are selected for machine learning.

Approach 1 might give accurate results but very time consuming, while approach 2 can be executed with minimal time. Approach 1 might give better result as it covers all available RGB combinations. But with approach 2 some RGB combinations required for actual analysis, might be missed out as we are finding each blob's maximum RGB combination individually while machine learning. For that we are proposing the advanced approach 3, which is faster as compare to approach 1 and eliminates the deficiency of approach 2. This approach will have algorithmic change in step-2 instead of step-1.

6.7 Approach 3

With approach 2, we are having very less number of RGB combinations in xml configuration file. So there might be chance that the foreign element, appears in actual sample doesn't have exact RGB combinations appears in input configuration file. The reason being, some identified RGB combinations with step-2 might have nearer RGB combinations value with the combinations resides in xml configuration file. Because of that the foreign elements will not be categorized correctly which has same visual effect but not considered while machine learning in step-1. The main issue with the approach 2 is that we are trying to map exact RGB combination value with xml configuration file vale. While categorisation if we try to consider all nearer RGB combinations in xml file, then we can also classify foreign elements correctly which are missed out with approach 2.

So deal with, it is required to find some techniques which can identify all the nearer set of RGB combinations in configuration file. And these identified combinations should be used for categorisation of foreign elements instead of exact mapping.

In approach 2, the direct RGB combinations values were checked. While in this approach 3, we have used different methods for comparing RGB values with pre-configured values which is described below:

1. Get the difference of R value of actual seed and the R value appearing in xml configuration file called distR.

2. Get the difference of G value of actual seed and the R value appearing in xml configuration file called distG.

3. Get the difference of B value of actual seed and the R value appearing in xml configuration file called distB.

4. Find the square of distR, distG and distB and make summation.

5. Make square root of it, called it as distance.

6. Check if the distance appearing in threshold range, then consider it as match.

7. Repeat the step 1 to 6 for every identified blob until match in step 6.

6.8 Comparisons and discussions of all approaches

Whole process is classified in two steps: *1. Machine learning 2.Actual sample analysis.* With approach 2 changes are done to make step 1 better *(step 1 (approach2) + step 2 (approach 1))*. With the approach 3 changes are done to make step 2 *(step 1 (approach2) + step 2 (approach 3))*. Any of the permutation combinations can be worked out for different quality results.

With the discussed approaches, foreign elements identification and classification can be done effectively based on RGB color combinations. It gives more than 80% accuracy, as customisation is done by end-users only. Different calibration files can be generated for different varieties of grain. Same imaging setup and same algorithmic approach can be also used for different type of grains. One time effort needs to be put for machine learning to generate calibration file. Then after, same calibration file can give consistent result for the particular type of grain samples.

CHAPTER – 7

Implementation

We have used the of Aforge.Net Image Processing library (AForge Imaging Library 2017). Aforge.net is an open source C# framework designed for developers and researchers in the fields of computer vision, artificial intelligence, image processing, neural networks, genetic algorithms, fuzzy logic, machine learning and robotics.

7.1 Technologies Used

Implementation is made using Microsoft Visual Studio 2012 and Microsoft .Net framework 4.5. Implementation is started using Matlab 7.8.0 (R2009a) to prove the concept at initial level. Then after, we switched to .Net technology of Microsoft for getting better accurate results. Aforge. Imaging Library (freeware) is used to support few imaging functions. The whole system is developed in VB.Net and c#.Net technologies with .Net framework 4.5. For back-end Microsoft Access 2013 is used to manage the grain analyser database.

The framework is comprised by the different set of Libraries: Aforge.Imaging, Aforge.Vision, Aforge.Video, Aforge.Neuro, Aforge.Genetic, Aforge.Fuzzy, Aforge.Robotics, Aforge.MachineLearning. We have used Aforge. Imaging library which is a C#.net based framework.

7.2 Development Phases

Development is done in different implementation phases. Improvements are made and new features are added with subsequent phases.

Below is the phase's detail of implementation:

1st Phase (Initial Phase): Implementation is started with Matlab 7.8.0 to prove the objective. Then we switched to Microsoft .Net technology for better accurate results.

2ndPhase: Implementation is made using Microsoft .Net technologies for extracting individual kernel features. Based on that grain sample's average parameters are calculated. Facility is provided to view the individual parameters of particular seed.

3rd Phase: With this phase different filters are added. Filters include size, aspect ratio, area and chalkiness filters. It also provides facility of color based filtering of individual seeds i.e. red, green and yellow. Filters are also implemented to show broken as well as overlapped kernels.

Different rice varieties are added and related measurement parameters are added to make grain analyser database more robust. It was showing the individual parameters details of each seed in earlier stage but it was difficult to get the sample's parameters analysis at a glance. For that it is required to add visual analysis of the grain sample and graphs are added. Different bar graphs are added for length, width, area and aspect ratio. Pie charts are added for head count and color count.

4th Phase: Color calibration mechanism *[ref.chap.5]*is provided for better classification of organisaiton choice. In fourth phase the efforts are put to make system standardise. ARSO and CODEX standards are added for that.

5th Phase: With this phase system is converted to web based for using it worldwide. *[ref.chap.8]*.

7.3 Algorithm

Captured image is given for processing to grain analyser. For processing, first it is required for identification of individual kernels in the input image. Labeling algorithm is used to get the total number of regions in a given image by joining of the connected pixels. The labeling algorithm scans the image row-wise and uses the merging algorithm in which a pixel receives the same label as its neighborhood pixel, if the pixels RGB values in threshold range then it will be labeled. It starts from first row and scans all pixels. For second row's first pixel it checks upper and upper right pixels. It checks surrounding connected pixels and proceed for one by one row. For last row it checks upper and upper left pixels. After scanning each pixel in image the label array is created.

While scanning it considered all pixels, but at the time of actual processing smallest acceptable size of a region, can be defined by the user in configuration file. The labeled image was examined and it will reject all the small regions, thereby eliminating noise and unwanted particles from the main image. With this labeling procedure, it was easy to calculate maximum and minimum spatial coordinates, fullness, center of gravity, area, color and other related parameters. For calculating the size and shape related individual and average features of grains, it is important to detect each grain in the image. The sufficient contrast is maintained between background and the grains. The background threshold value was kept constant for analysis of all the images.

Below algorithm shows the overall process of gain analyser:

1. Select image
2. Filtering image (Color filter)
3. Detecting objects
    - 3.1 Building Objects map
        - 3.1.1 Build Object map - Process the image and builds objects map, which will be used to extract blob. Blob is interested region of image which is identified after subtracting background. (Return object labels)
        - 3.1.2 Collect Objects map – (Return blobs)
4. Filter blobs based on dimension
5. Get blobs edge points for angle
6. Calculate angle and apply rotation filter
7. Apply chalk filter
8. Apply convex hull for showing filtered seeds
9. Filter button click (Filter seeds)

7.4 Intermediate Outputs

This section throws light on the experiments carried out for supporting the research. Fig. 7.1 (a) shows the captured grain sample using scanner and Fig. 7.1 (b) shows the segmented image of it. Red colored boundary showed for the identified seed in segmented image.

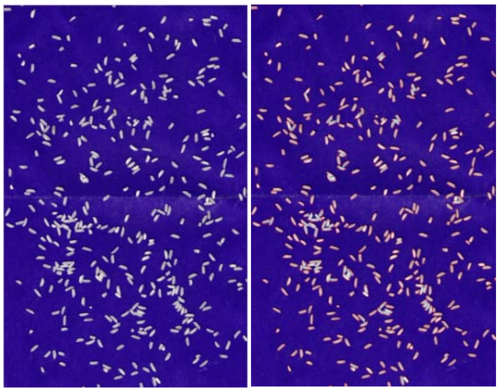


FIGURE 7.1: Rice sample image (a), segmented image (b)

7.5 GUI (Graphical User Interface) Forms

System is designed with different GUI forms listed below. Granule level functionalities are clubbed either of the below mentioned form/s.

1. Login form (frmLogin.vb)
2. Main form (frmMainGUI.vb)
3. Grain sample scan form (frmScan.vb)
4. Graph form (frmGraphs.vb)
5. Single seed detail form (frmSingle.vb)
6. Calibration form (frmCalibration.vb)

7.5.1 Login Form

It is useful for validating user. Only authenticated user can access the system. Rights are given for user role as read only, update access, and generate report.

Readonly rights are for the user who wants to use the system for measuring the quality parameters for the grain sample image given as input to the system. ***Update access*** is given to user who wants to change the configuration parameters like length mean, width mean, area mean, Standard deviation in length, standard deviation in width and standard deviation in area. These configuration parameters are act as an input to the system and based on them any grain sample quality is determined. If the configuration parameters are changed, then different quality results may occur for the same sample analysis. These configuration parameters need great care while updating, as it impact final quality results. ***Generate report*** rights are given to the users who wants to generate graph of the results in accordance to quality parameter measurements.

7.5.2 Main Form

This form provides the top level graphical interface to the whole system. After logging to the system this is the first welcoming screen to the system. It provides the menu for selecting the input grain sample image, generate calibration file, logout to the system and exit to the system.

7.5.3 Grain sample scan form

This is the very important form among all. This form is opened by clicking the “NEW” menu on Main Form.

It has below mentioned sections and related controls are attached to them.

Standards: This section is for showing the standards for the grain selected Grain Category section. It shows *length mean, width mean, area mean, Standard deviation in length, standard deviation in width* and *standard deviation in area* of the selected grain.

Grain Category: Grain category section is useful for selecting the grain i.e. rice, wheat, lentils, sesame, maize, Chickpeas etc. After selecting grain, the next option is to select the variety of that particular grain. This gives selections based on the grain selected. i.e for rice grain the selections are given as BasmatiRicePR12, BasmatiRicePR10, BasmatiRicePR07, GR-3, GR-4, GR-7 etc. A last selection is for selecting standard. This selection is for providing input of different standards based on which output quality parameters are generated. Standards vary from organisation to organisation, and the results must be generated in accordance to the standards followed by the organisation using this grain analyser.

Scan grain sample: This functionality is for selecting the grain sample image.

Analyse the sample: This functionality is for starting the quality analysis process of the grain sample. With this, the grain sample is analysed, quality parameters are generated and results are shown to related sections based on the input selections. In background the main process is triggered with this option.

Graphs generation: This functionality is for generating the graphs for the selected grain sample. Graphs are generated based on the quality parameters measured by analysis process.

Sample Results: This section shows the no. of seeds falling in particular category. This is divided based on standards from top level. Inner parameters show the different category associated with particular standards. Data values are filled after sample is analysed. Only those values are fields after analysis process, for which standards are selected in standards section.

Color: This section is useful for showing the no. of seeds falling in particular color range. Results are generated either by default color range (in case of calibration file doesn't exist) or based on calibration file provided as input.

Average: This section provides the information about the measured average parameters of the analysed grain sample. It includes average length, average width, average area, average aspect ratio and average chalkiness.

Filters: This section is for filtering only those seeds which satisfies particular conditions. Based on selected filter criteria, only those seeds are highlighted in the main grain sample image which falls under the filter conditions. Filters are given for size, color and chalkiness based on different selected standards.

Fig. 7.2 and Fig. 7.3 show the segmented images for red and green cololred filtered analysis respectively.

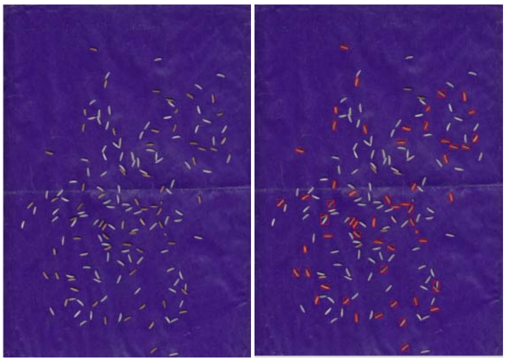


FIGURE 7.2: Rice mixed with Red color seeds (a), Red seeds filtered (b)

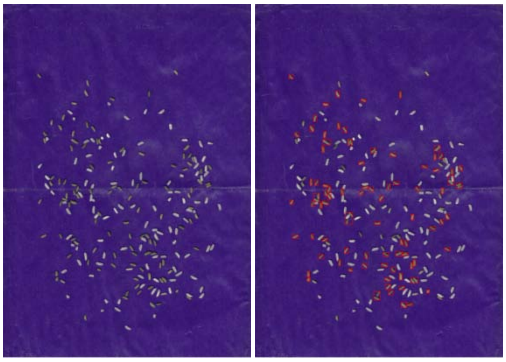


FIGURE 7.3: Rice mixed with Green color seeds (a), Green seeds filtered (b)

7.5.4 Graph Form

Graph form can be open by pressing the "Graph" button on *grain sample scan form.* It provides the facility of generating different kind of graphical output for the analysed grain sample.

Below mentioned graphs are generated.

Length graph: This bar graph shows the number of seeds falling under particular length in form of the bars. This graph provides the facility of generating the graph by varying X-Axis maximum range, X-Axis interval and count interval (Y-Axis interval). Fig.7.4 shows the length distribution graph.

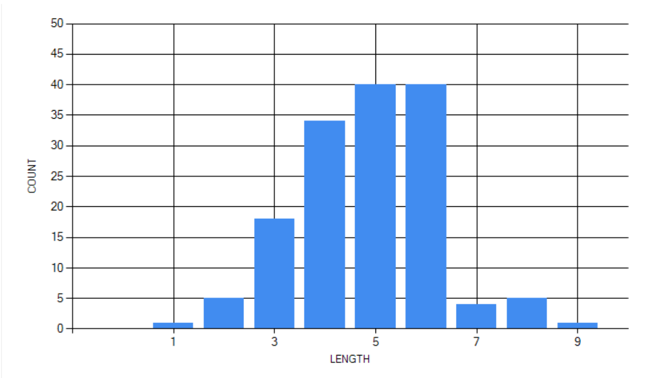


FIGURE 7.4: Length Graph

Width graph: This bar graph shows the number of seeds falling under particular width in form of the bars. This graph provides the facility of generating the graph by varying X-Axis maximum range, X-Axis interval and count interval (Y-Axis interval).Fig. 7.5shows the width distribution graph.

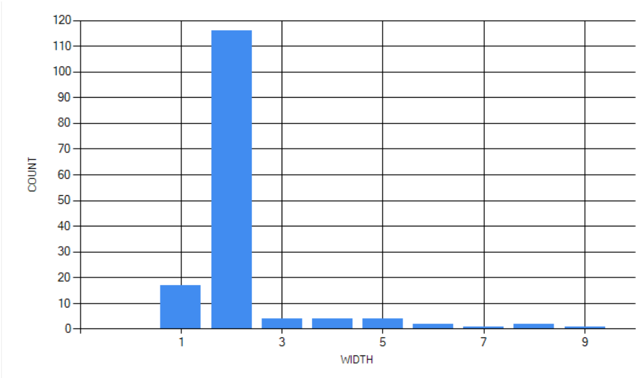


FIGURE 7.5: Width Graph

Area graph: This bar graph shows the number of seeds falling under particular area in form of the bars. This graph provides the facility of generating the graph by varying X-Axis maximum range, X-Axis interval and count interval (Y-Axis interval). Fig. 7.6 shows the area distribution graph.

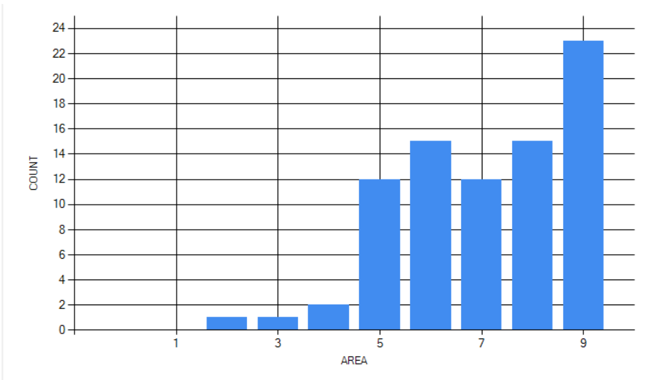


FIGURE 7.6: Area Graph

Aspect ratio graph: This bar graph shows the number of seeds falling under particular aspect ratio in form of the bars. This graph provides the facility of generating the graph by varying X-Axis maximum range, X-Axis interval and count interval (Y-Axis interval). Fig. 7.7 shows the aspect ratio distribution graph.

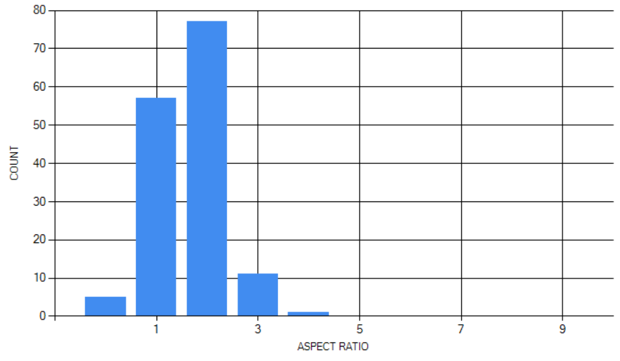


FIGURE 7.7: Aspect Ratio Graph

Head count: This pi-graph is useful for generating the percentage detail of the no. of seeds falling under the particular size. This graph may vary based on ***standards*** selected with the ***grain sample scan form***. Fig. 7.8 and Fig. 7.9 show the fullness distribution graph for ARSO and CODEX standard respectively for the same grain sample.

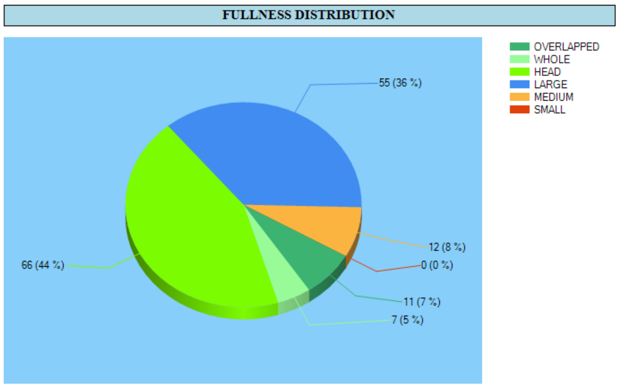


FIGURE 7.8: HeadCount (Fullness) Graph - ARSO standard

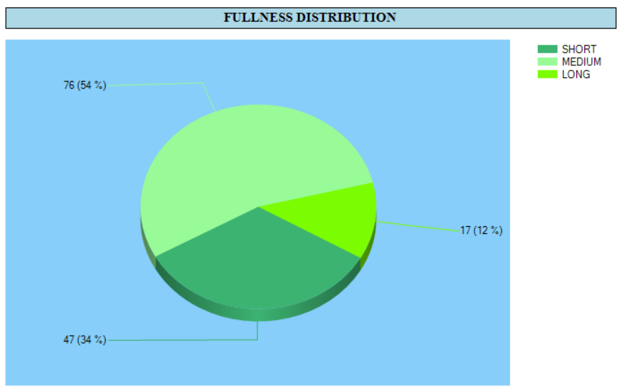


FIGURE 7.9: Head Count (Fullness) Graph – CODEX Standard

Color count: This pi-graph is useful for generating the percentage detail of the no. of seeds falling under the particular color range.

Other types of different graphs can be added to this functionality by just changing the input parameters and providing type of graph.

7.5.5 Single seed detail form

This form is useful for getting the individual seed detail. This form opens by hovering the mouse control on a particular seed. It gives the parameter value of that particular seed i.e. length, width, aspect ratio, area, color set, exact color, seed type etc.

7.5.6 Calibration form

This form is useful for generating calibration file. Training data set is analysed and calibration files are generated using this form. After analysing the grain sample image, it gives the different RGB combinations value and related count to it. User can categorise them and provide name of organisation choice. The mapping of RGB combinations value and their group names are stored in calibration file.

7.6 Summary

The desktop implementation of grain analyser is developed first. Facility is provided for extracting individual kernel features. Color filters are added to provide size, aspect ratio, area and chalkiness classification. ARSO and CODEX standards are introduced for standardizing the system. Finally, efforts are made for web based implementation to use grain analyser worldwide which is described in next chapter.

CHAPTER – 8

Web Based Implementation

The previous chapter discusses about desktop implementation of grain analyser. It accommodates various standards of grain analysis specified by various organisations. In addition to it, for better utility and expediency it is required to make system online and centralised.

After providing all features of offline grain analyser the developed grain analyser is only useful for small scale organisation. The main reason behind that is, there are chances when the scanner and processing machine are not at the same place. In that case it is required to backup grain image in some backup drive and needs to be send to processing machine. After analysis, the results must be saved to the backup drive and sent to the consumer.

To get rid of this it is required to put features of online grain analyser too. Online grain analysis techniques have their own challenges which need to be overcome while development. Grain analyser is developed with disconnected architecture by considering the above discussion. Many new features are introduced to developed offline grain analyser for making system web-based.

We have used the Microsoft Visual Studio 2012 and Microsoft .Net framework 4.5 for implementation of web based system.

8.1 Background

Offline analysis techniques are developed with first four development phases *[chap. 7]***.**The developed system with these phases can be used with small scale organisation. With growing grain market it is required to make the system centralised. In offline grain analyser, the grain scanner is connected to computerised machine. Grain sample is analysed and result can be seen on machine which is nearby. This is useful when only bulk's sample needs to be analysed. This technique is time consuming when whole bulk itself needs to be analysed. For that mainly online image based grain analysis technique is used. With online grain analysis techniques, whole bulk images are captured in a row by using conveyer belt. These images are sent to processing machine. Grain analysis is done in parallel, while grain is passing through conveyer belt. Analysis result can be seen by the machine which is generally connected using local area network (LAN). This is useful for medium scale organisation.

We have developed the grain analysis technique which can be used for large scale organisation. To deal with that, it is required to make the robust system which can work above LAN layer. For that web based system is introduced, which can be used via internet. The prime advantage with this is, it can be used from anywhere in the world wherever internet facility is available.

8.2 Technologies Used

As it is web based techniques, system is required to implement in two modules. One module will work at server side and other module will work at client side. Different tools and technologies are used as given below:

8.2.1 Server Side Technologies:

- ***Tool:*** Microsoft Visual Studio 2012
- ***Framework:*** .Net Framework 4.5
- ***Language:*** VB.Net, C#.Net
- ***Database:*** Microsoft SQL server 2008

8.2.2 Client Side Technologies

- ***Tool:*** Microsoft Visual Studio 2012
- ***Framework:*** .Net Framework 4.5
- ***Language:*** C#.Net

8.3 Client-Server Architecture

The workload of whole system is divided in two partitions, client and server (Fig. 8.1). Client and server communicate over a computer network. Generally internet is used for networking purpose. Client and server may reside in same system. This option is useful for small scale organisation. However for large scale organisation many clients can communicate with server at a time. At that time this architecture will be useful for handling multiple requests in parallel. Client can be desktop machine, laptop machine or mobile.

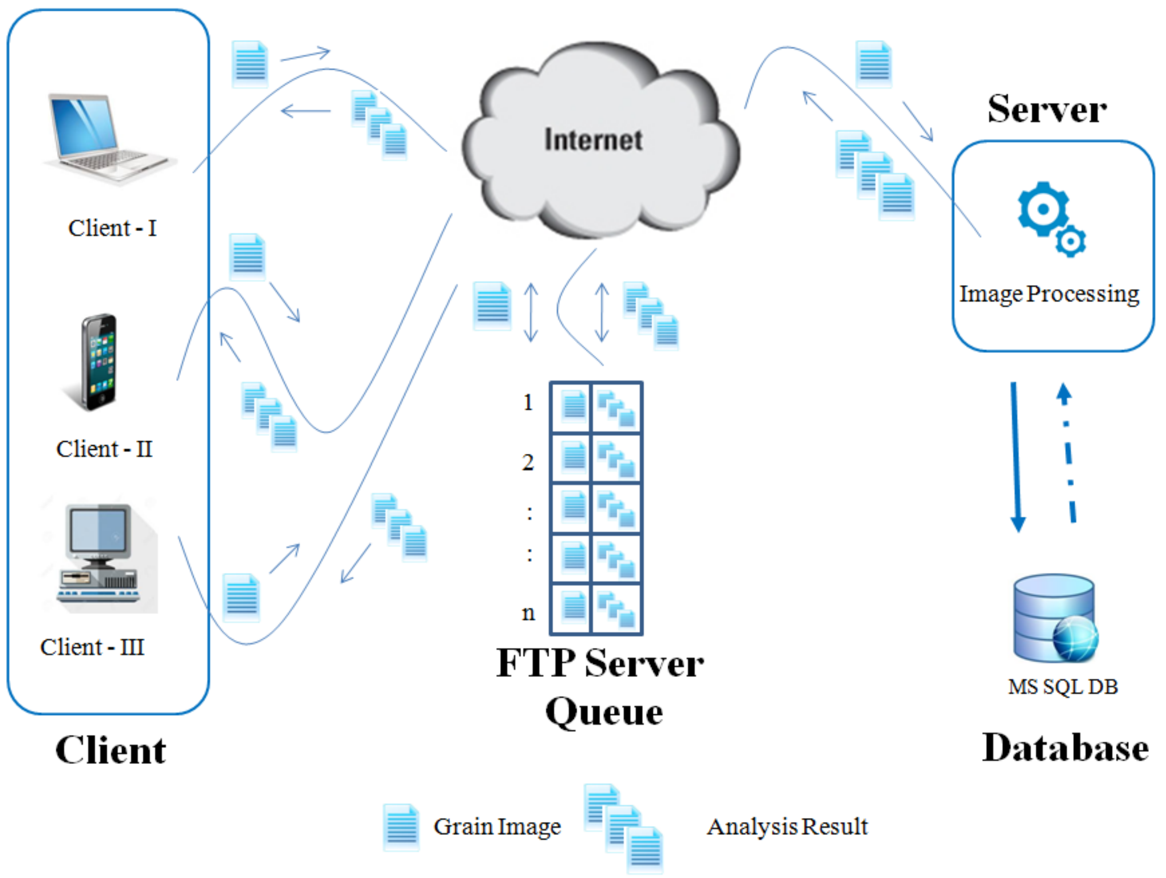


FIGURE 8.1: Web Based Architecture

8.4 Workflow of the developed system

Algorithm steps execute in sequence are:

1. Client captures the grain sample images.
2. Client uploads captured images to ftp server queue (via internet) by resetting the flag value.

3. Server takes grain sample image from queue.
4. Server process grain sample image.
5. Server generates output / analysis images.
6. Server sets flag value.
7. Server updates the database for processed image.
8. Server uploads all output images to ftp server via internet and creates links to those images.
9. Server gets the next grain sample image from ftp server queue and repeat step 4 to step 8 until queue is empty.
10. Client clicks the different links on detail web forms *[ref. 8.6]* to see the grain sample analysis images.

8.5 Disconnected architecture

Disconnected architecture is the main advantage provided with this research. It can even work when either client or server goes off. When client goes off, the sever takes the files from FTP server and saves the generated results on FTP server itself. And when the server goes down the client can upload the image files to FTP server.

Online grain analysers show the analysis result of grain sample which is passing through conveyer belt. Next, image is captured while previous image is under processing by analyser. Both things happen in parallel, so faster processing machine is required otherwise there is chance missing few grains from processing. Online grain analyser would have the conveyer belt and processing machine nearby, which is connected by LAN. This type of grain analysers are used within organisation. It only handles the images which are captured by the camera above conveyer belt.

With this research, we have proposed disconnected architecture. Instead of continuously capturing and processing all grain images, the queue mechanism is implemented. This queue resides on ftp server. Images uploaded by client first put into this queue. Sever takes one by one image from queue and process it. If queue is empty then server would be in continuously listen mode. It starts processing as soon as new image is arrived on ftp server queue for processing. After processing, various analysis images are generated as a result. Generated analytical images are put in ftp server queue. These images can be visited any time at client end until it is specifically deleted.

8.6 GUI (Graphical User Interface) Forms

At client side below web forms are provided for interface:

1. Login form
2. Main form
3. Detail form

8.6.1 Login Form

Login form (Fig. 8.2) is useful for user authentication. This is the visiting form of the developed web application. User needs to login first for using the grain anlayser.

There are two different kinds of role for users:

1. ***Admin:*** This user has highest privileges of modifying system settings for processing the grain images. It has full access of the web application.

2. ***Standard user:*** This user role is basic user role for uploading the grain images to ftp server. After processing user can view the processed results. This user can not modify any system settings.

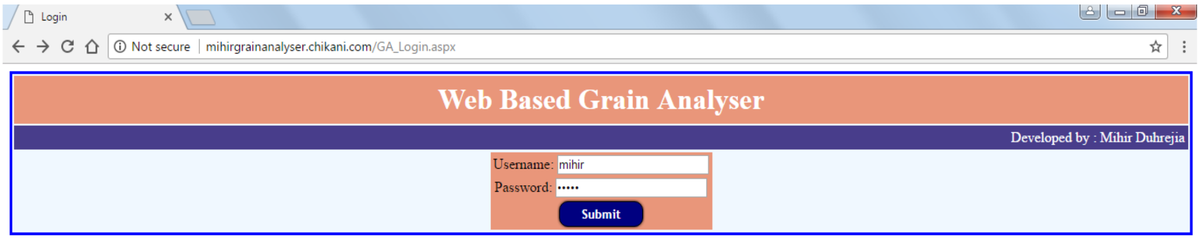


FIGURE 8.2: Login Form

8.6.2 Main Form

Main form (Fig. 8.3) is useful for uploading the grain sample image. Different options are provided while uploading the image. Based on options selection the analysis result will be generated.

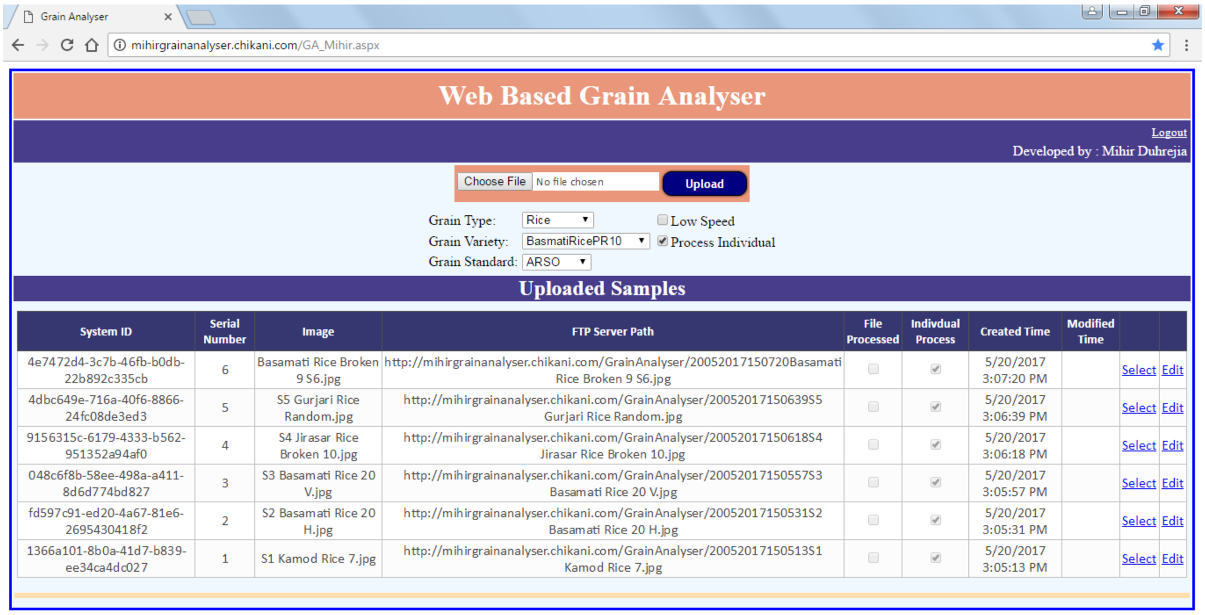


FIGURE 8.3: Main Form (files uploaded for processing)

Upload control is useful for selecting and uploading grain sample file. On click of upload button the file dialogue box is opened. After selecting grain sample file from file dialogue, click on the upload button to upload the file to ftp server.

Grain Type combobox is for selecting the grain i.e. rice, wheat, lentils, sesame, maize, chickpea, green gram etc. After selecting grain, the next option is to select the variety of that particular grain.

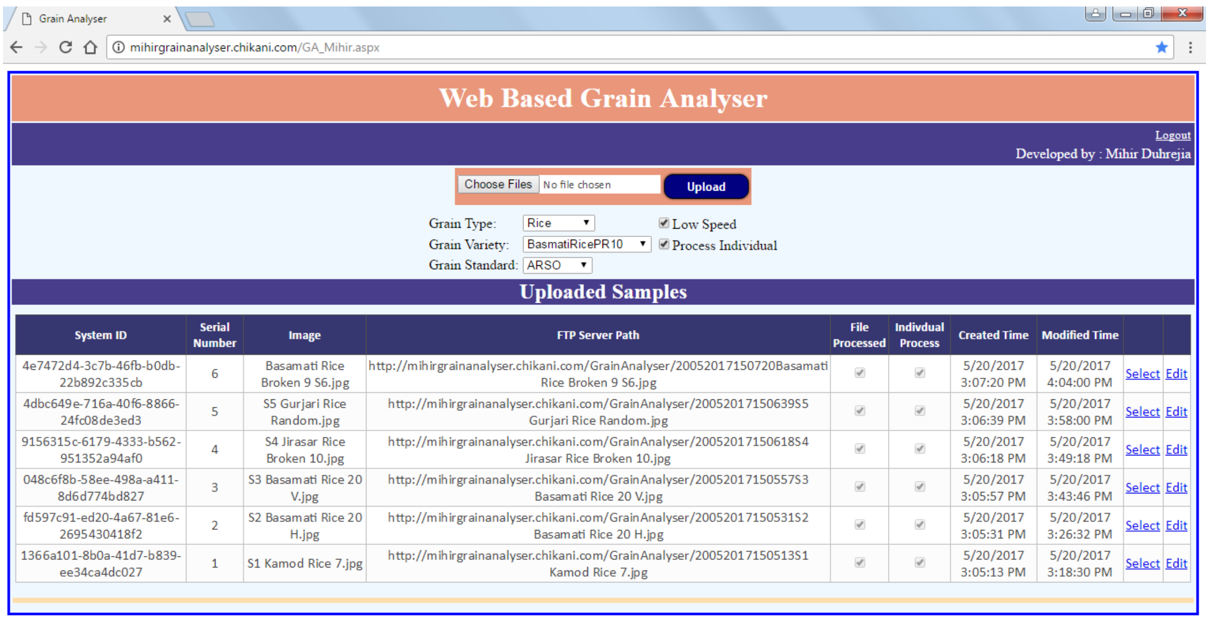
Grain variety combobox gives different choice based on the grain selected i.e. for rice grain the selections are given as BasmatiRicePR12, BasmatiRicePR10, BasmatiRicePR07, GR-3, GR-4, GR-7 etc.

Grain Standard combobox option is for selecting different standards. Based on selected standard quality analysis is performed. As standards vary from organisation to organisation, the results must be generated in accordance to the standards followed by the organisation. This option helps in customisation of analysis results based on organisation choice.

LowSpeed check box is for providing inputs regarding the speed of network. It is required to check if the speed is slow. When this option is enabled, all output images are converted to thumbnails before uploading to ftp server. Thumbnails significantly reduce the actual image size, which saves network traffic.

Process Individual check box is for selecting the individual seed needs to be processed or not. This option is useful when the only interest for the average analysis results. This option is required as grain sample may contain more than 100 seeds. For every seeds, one analysis image is generated. That many numbers of images needs to be uploaded to ftp server via internet. For getting quick results, the individual analysis can be skipped by un-checking "*Process Individual*" checkbox. Text file is generated every time which is an alternate for getting the individual seed analysis without generating their images as shown in (Fig. 8.17).

Grid view is for displaying the grain sample images which are uploaded to the server. It also gives the idea about the file is processed by server or not. It also provides the information regarding uploaded image location on ftp server. Grid also shows the file created time on ftp server and modified time of that particular grain image file. Option is provided for navigating to detail form by clicking *select* hyper link. When files are uploaded at that time "*File processed*" check box would be unchecked and "*Modified Time*" would be blank as shown in Fig. 8.3 for all uploaded files. After processing all files the "*File Processed*" becomes checked for all files and "*Modified Time*" value is updated in the grid view for all files respectively as shown in Fig. 8.4.



Grain Analyser
mihirgrainanalyser.chikani.com/GA_Mihir.aspx

Web Based Grain Analyser

Logout
Developed by : Mihir Duhrejia

Choose Files No file chosen Upload

Grain Type: Rice ☑ Low Speed
Grain Variety: BasmatiRicePR10 ☑ Process Individual
Grain Standard: ARSO

Uploaded Samples

System ID	Serial Number	Image	FTP Server Path	File Processed	Indivdual Process	Created Time	Modified Time		
4e7472d4-3c7b-46fb-b0db-22b892c335cb	6	Basamati Rice Broken 9 S6.jpg	http://mihirgrainanalyser.chikani.com/GrainAnalyser/20052017150720Basamati Rice Broken 9 S6.jpg	☑	☑	5/20/2017 3:07:20 PM	5/20/2017 4:04:00 PM	Select	Edit
4dbc649e-716a-40f6-8866-24fc08de3ed3	5	S5 Gurjari Rice Random.jpg	http://mihirgrainanalyser.chikani.com/GrainAnalyser/20052017150639S5 Gurjari Rice Random.jpg	☑	☑	5/20/2017 3:06:39 PM	5/20/2017 3:58:00 PM	Select	Edit
9156315c-6179-4333-b562-951352a94af0	4	S4 Jirasar Rice Broken 10.jpg	http://mihirgrainanalyser.chikani.com/GrainAnalyser/20052017150618S4 Jirasar Rice Broken 10.jpg	☑	☑	5/20/2017 3:06:18 PM	5/20/2017 3:49:18 PM	Select	Edit
048c6f8b-58ee-498a-a411-8d6d774bd827	3	S3 Basamati Rice 20 V.jpg	http://mihirgrainanalyser.chikani.com/GrainAnalyser/20052017150557S3 Basamati Rice 20 V.jpg	☑	☑	5/20/2017 3:05:57 PM	5/20/2017 3:43:46 PM	Select	Edit
fd597c91-ed20-4a67-81e6-2695430418f2	2	S2 Basamati Rice 20 H.jpg	http://mihirgrainanalyser.chikani.com/GrainAnalyser/20052017150531S2 Basamati Rice 20 H.jpg	☑	☑	5/20/2017 3:05:31 PM	5/20/2017 3:26:32 PM	Select	Edit
1366a101-8b0a-41d7-b839-ee34ca4dc027	1	S1 Kamod Rice 7.jpg	http://mihirgrainanalyser.chikani.com/GrainAnalyser/20052017150513S1 Kamod Rice 7.jpg	☑	☑	5/20/2017 3:05:13 PM	5/20/2017 3:18:30 PM	Select	Edit

FIGURE 8.4: Main Form (all uploaded files are processed)

8.6.3 Detail Form

Detail form (Fig. 8.5) is used for displaying the different analysis result images. It opens when grain sample image is selected by clicking *select* hyperlink from the grid on main form. It shows the generated analysis output images for the grain sample, which is clicked on main form.

Gridview shows the list of all images generated by analysis process. It also shows the path where the image is uploaded to server. Last column of grid provides facility of the viewing image by clicking *select* hyper link. After clicking on *select* hyperlink the related image opens in the picture box next to it.

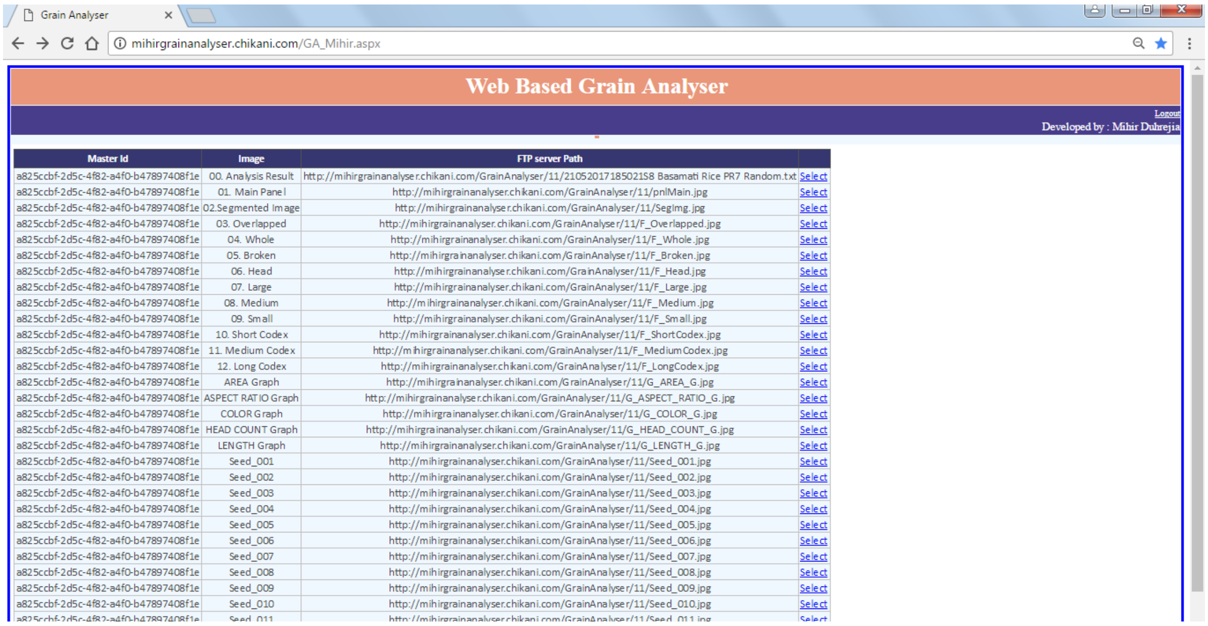


FIGURE 8.5: Detail Form

Picture box shows the image which is selected using hyperlink in grid view. When next image is selected the previous image is overwritten with selected image.

Detail form shows the images for main panel, segmented image (Fig. 8.6) and overlapped kernels (Fig. 8.7). Classification images are generated for whole, broken, head, large, medium, small, short codex, medium codex and long codex. For classification various filters are provided. While processing, for each filter selection related image is generated (Fig. 8.8. to Fig. 8.13), which can be seen by clicking *select* hyperlink in detail grid. It also generates bar graphs for the area, aspect ratio, length and width (Fig.8.14). It also provides the pie charts for the fullness distribution (head count) and color distribution (Fig.8.15). Headcount pie chart depends on the standard selected in main form. Grain analyser also provides facility for getting detail of each and every individual seed. For every individual seeds analysis result image is generated. Generated images show analysis result as seed_001, seed_002, seed_003….seed_00n, where n is the total number of identified seeds (Fig.8.16).

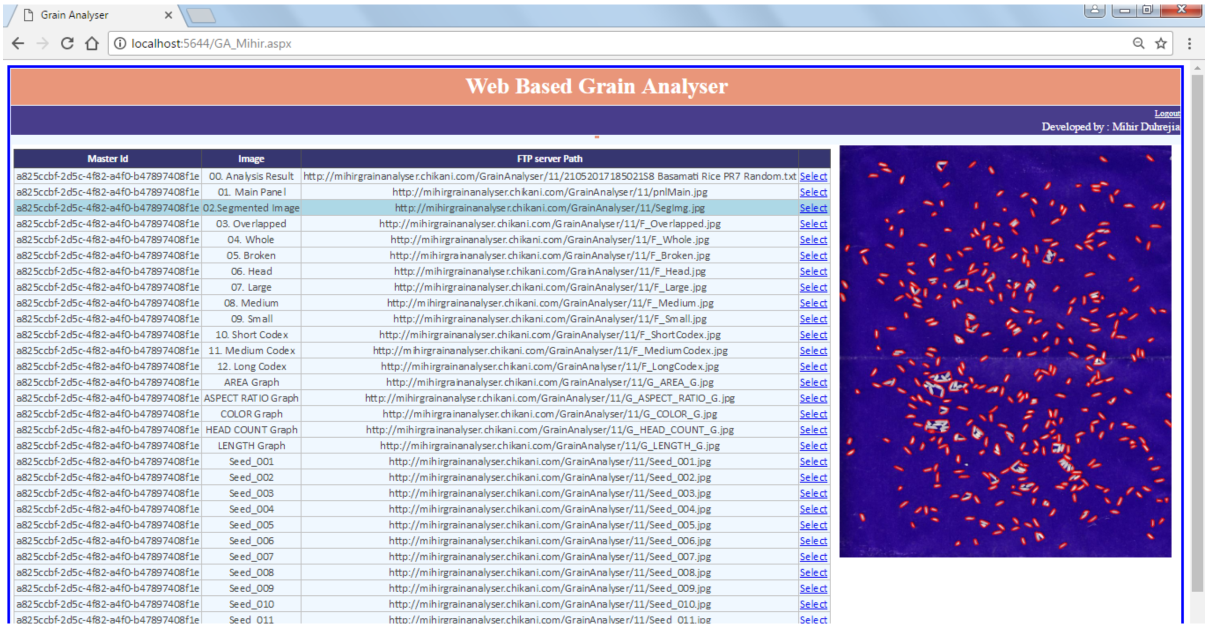


FIGURE 8.6: Detail Form (Segmented Image)

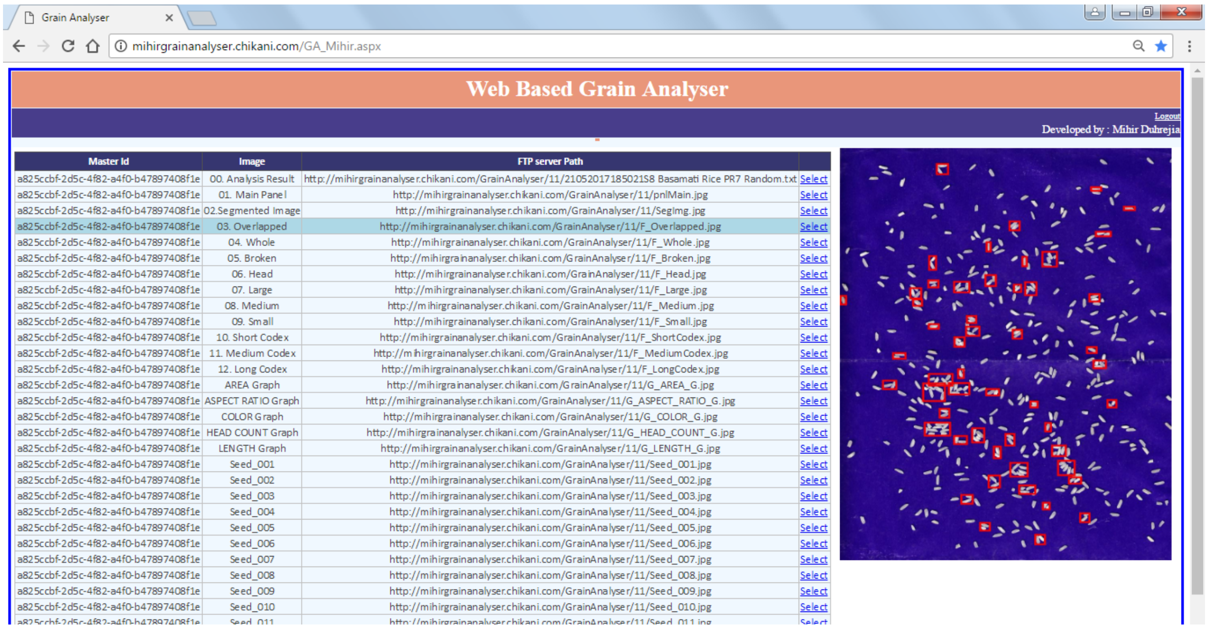


FIGURE 8.7: Detail Form (Overlapped)

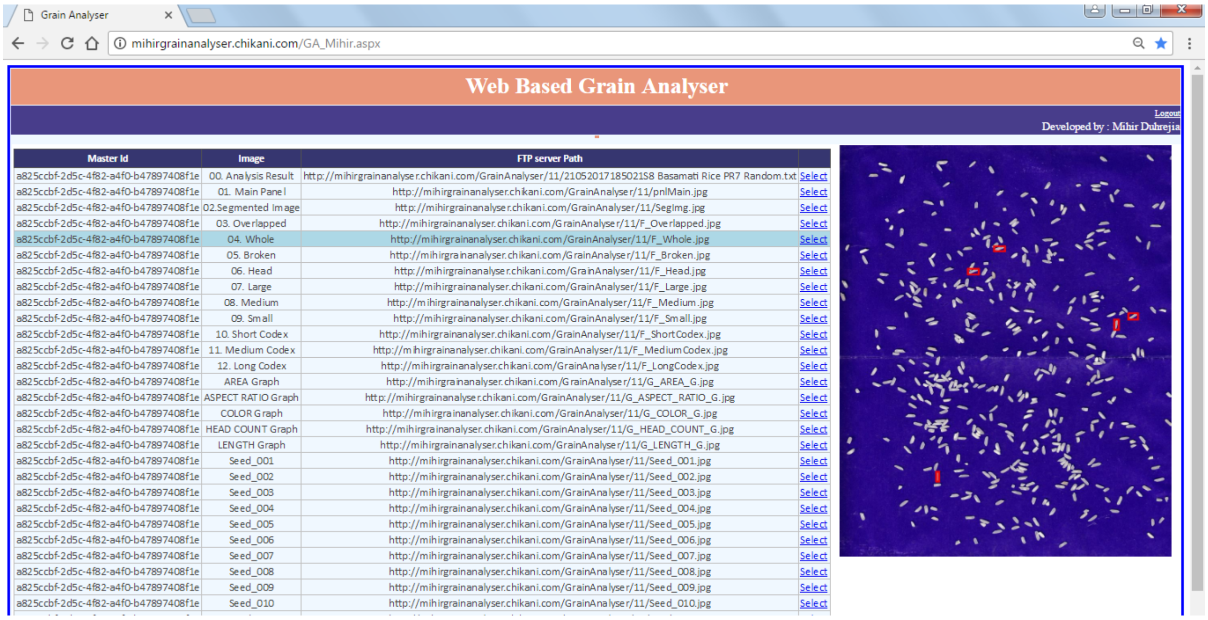


FIGURE 8.8: Detail Form (Whole)

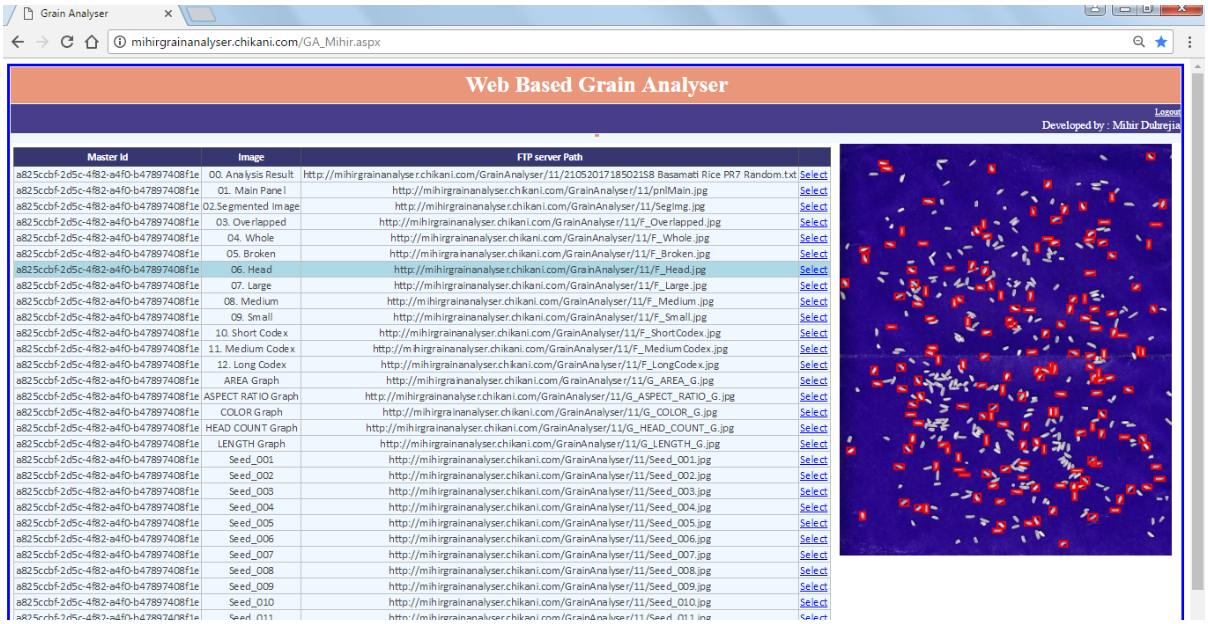


FIGURE 8.9: Detail Form (Head)

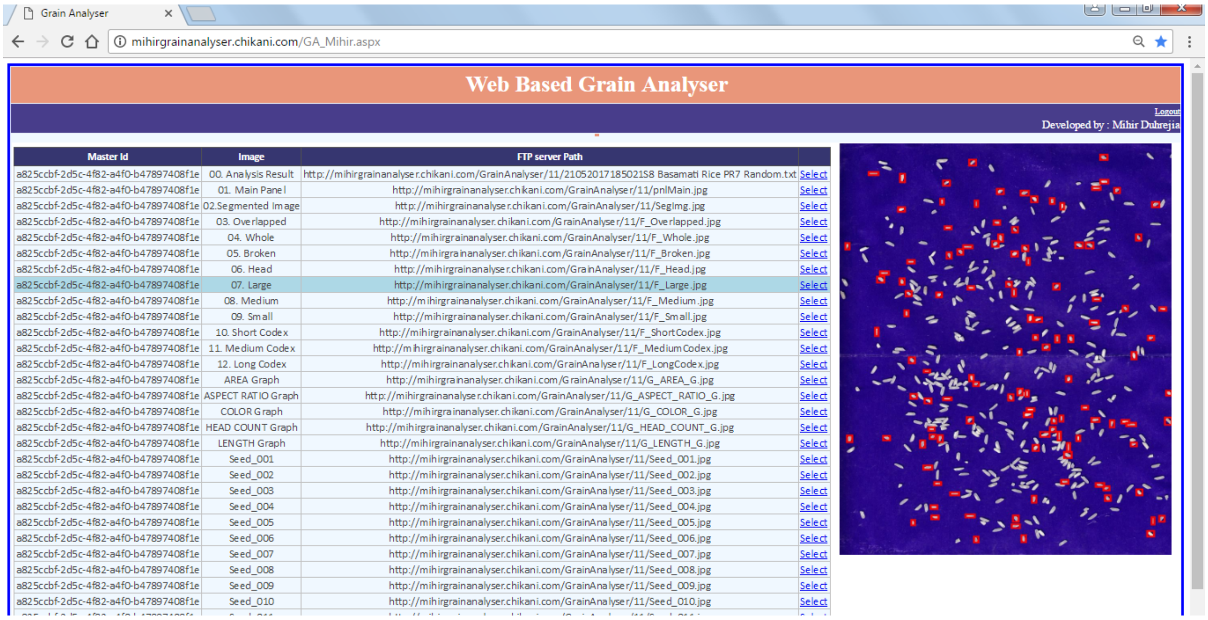


FIGURE 8.10: Detail Form (Large)

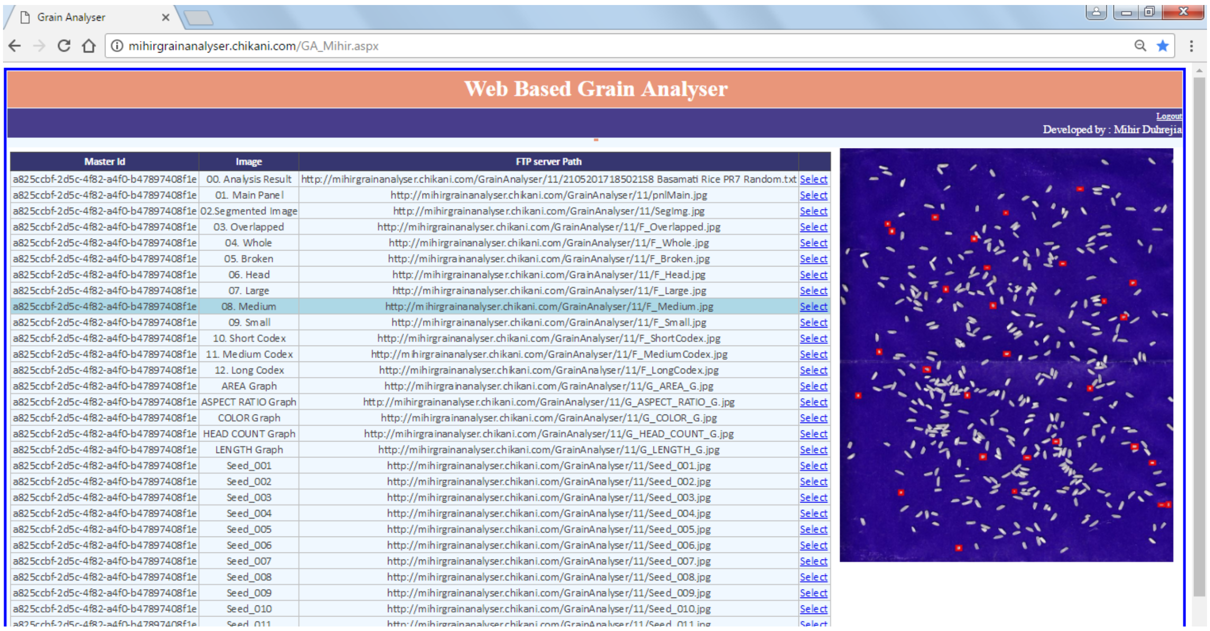


FIGURE 8.11: Detail Form (Medium)

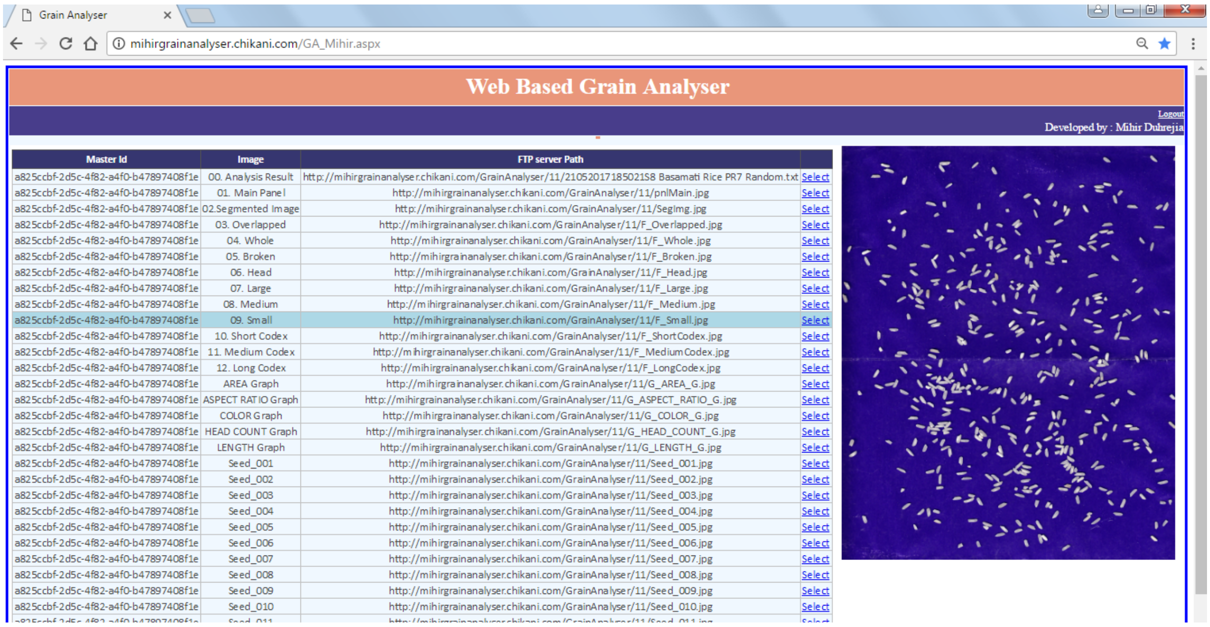


FIGURE 8.12: Detail Form (Small)

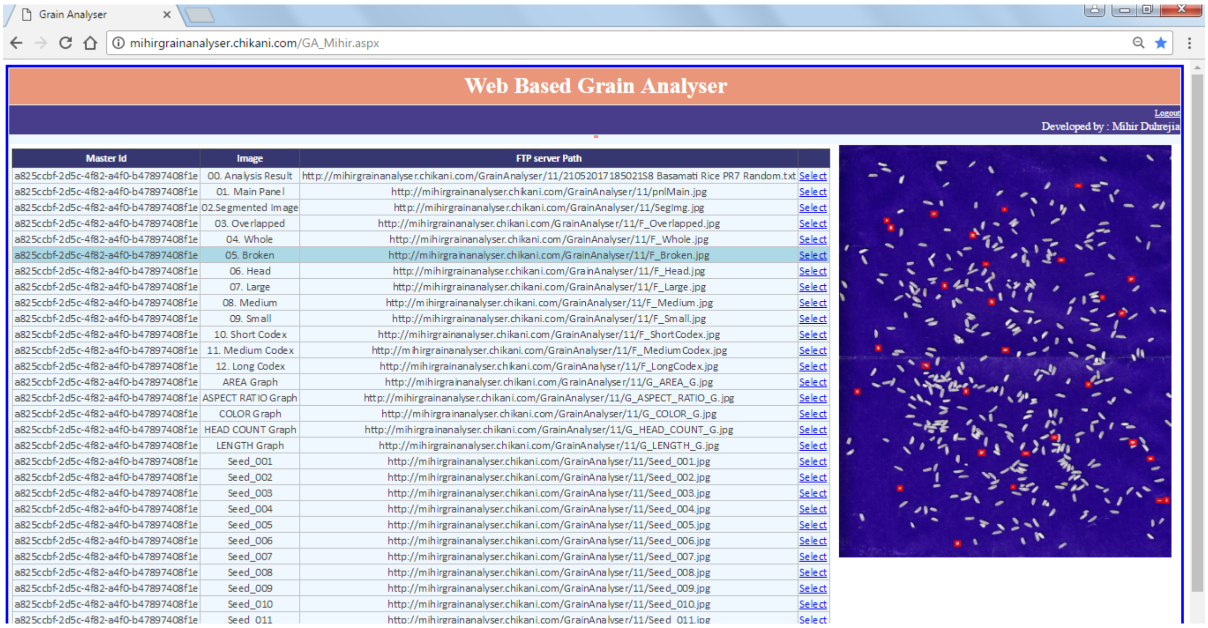


FIGURE 8.13: Detail Form (Broken)

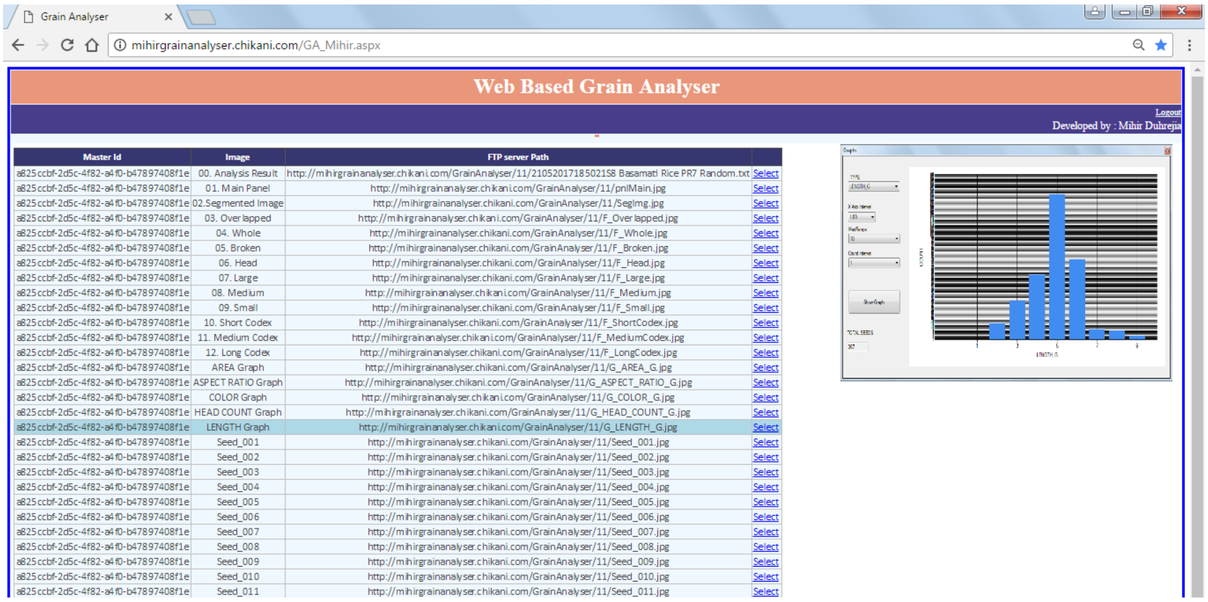


FIGURE 8.14: Detail Form (Bar Graph)

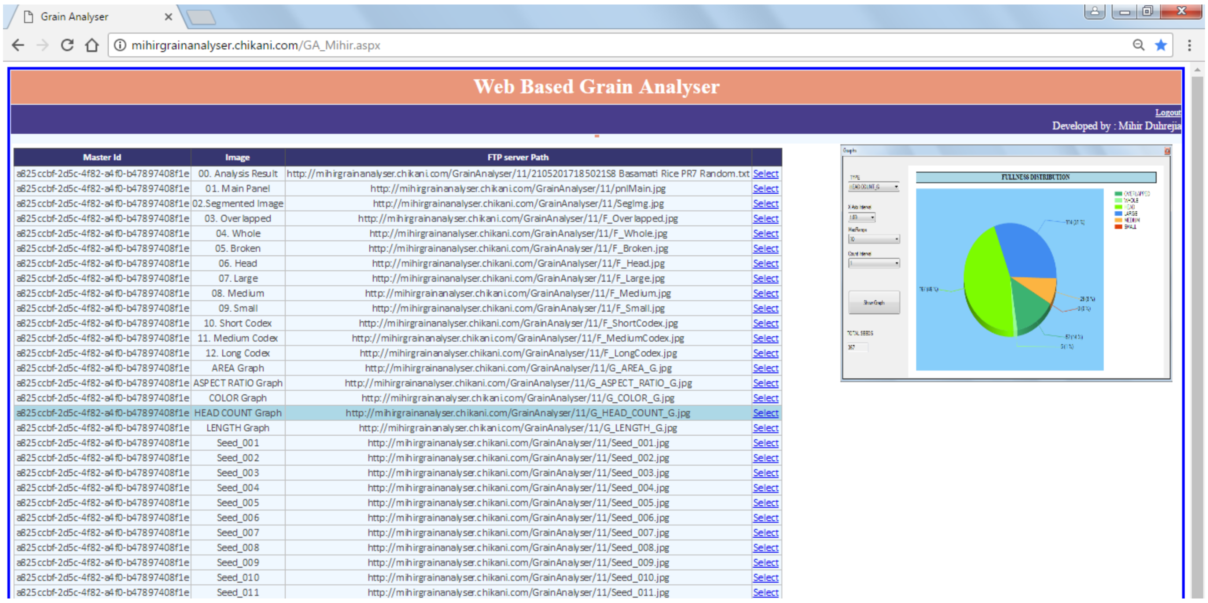


FIGURE 8.15: Detail Form (Pie Graph)

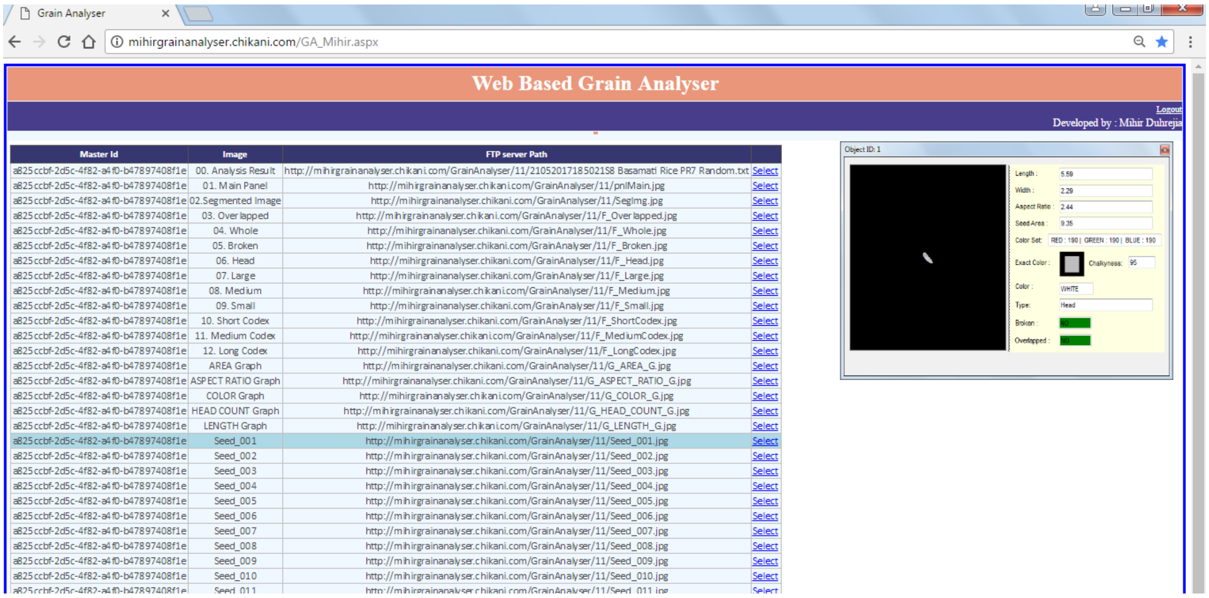


FIGURE 8.16: Detail Form (Individual Seed Id-001)

Image zooming facility is provided for getting clearer analysis images. To see image side by side, *select* link can be clicked on detail form and image shows on the same page at right hand side (Fig. 8.6 to 8.16). Particular image can be clicked for getting clearer picture. After clicking, web page is redirected to next page and the zoomed image of the selected image is shown in whole page as in Fig. 8.17.

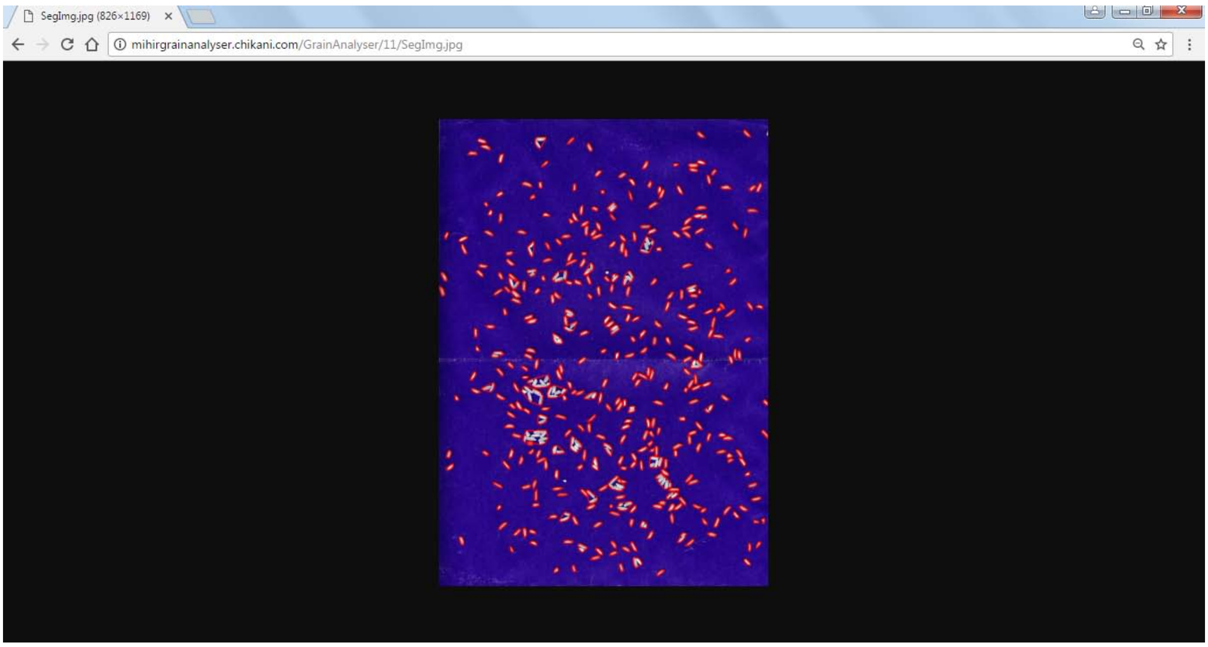
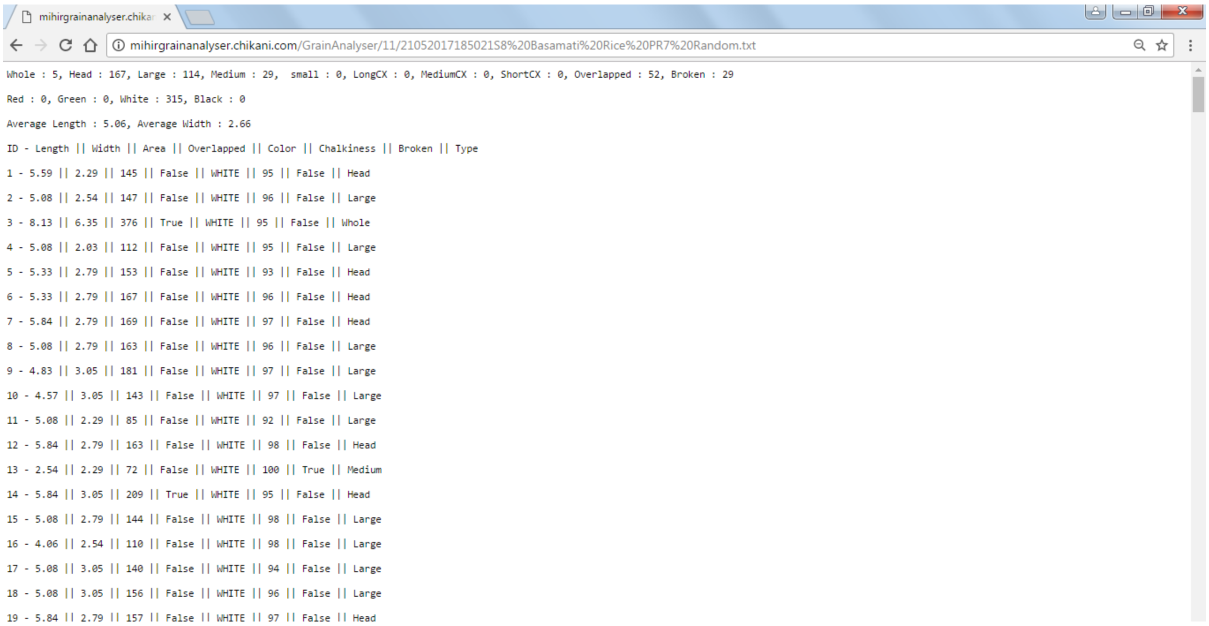


FIGURE 8.17: Segmented Image with Zooming

Text analysis result is generated to check the whole analysis result in single shot. Hyperlink can be clicked from grid view to see the consolidated result. After clicking, page is redirected to next page and analysis is shown as in Fig. 8.18. It shows the different numbers of seeds falls in particular length and color category. Color classification can also be checked with this analysis. It provides the measured average parameters value for the grain sample. It also shows the analysis result of all individual seeds.



```
mihirgrainanalyser.chikani.com/GrainAnalyser/11/21052017185021S8%20Basamati%20Rice%20PR7%20Random.txt

Whole : 5, Head : 167, Large : 114, Medium : 29,  small : 0, LongCX : 0, MediumCX : 0, ShortCX : 0, Overlapped : 52, Broken : 29
Red : 0, Green : 0, White : 315, Black : 0
Average Length : 5.06, Average Width : 2.66
ID - Length || Width || Area || Overlapped || Color || Chalkiness || Broken || Type
1 - 5.59 || 2.29 || 145 || False || WHITE || 95 || False || Head
2 - 5.08 || 2.54 || 147 || False || WHITE || 96 || False || Large
3 - 8.13 || 6.35 || 376 || True || WHITE || 95 || False || Whole
4 - 5.08 || 2.03 || 112 || False || WHITE || 95 || False || Large
5 - 5.33 || 2.79 || 153 || False || WHITE || 93 || False || Head
6 - 5.33 || 2.79 || 167 || False || WHITE || 96 || False || Head
7 - 5.84 || 2.79 || 169 || False || WHITE || 97 || False || Head
8 - 5.08 || 2.79 || 163 || False || WHITE || 96 || False || Large
9 - 4.83 || 3.05 || 181 || False || WHITE || 97 || False || Large
10 - 4.57 || 3.05 || 143 || False || WHITE || 97 || False || Large
11 - 5.08 || 2.29 || 85 || False || WHITE || 92 || False || Large
12 - 5.84 || 2.79 || 163 || False || WHITE || 98 || False || Head
13 - 2.54 || 2.29 || 72 || False || WHITE || 100 || True || Medium
14 - 5.84 || 3.05 || 209 || True || WHITE || 95 || False || Head
15 - 5.08 || 2.79 || 144 || False || WHITE || 98 || False || Large
16 - 4.06 || 2.54 || 110 || False || WHITE || 98 || False || Large
17 - 5.08 || 3.05 || 140 || False || WHITE || 94 || False || Large
18 - 5.08 || 3.05 || 156 || False || WHITE || 96 || False || Large
19 - 5.84 || 2.79 || 157 || False || WHITE || 97 || False || Head
```

FIGURE 8.18: Text Analysis of Grain Sample

8.7 Web Application Security

User detail is saved in session at server end. If any of the web pages is accessed directly by bypassing authentication then this request is automatically redirected to the login form *[ref. 8.6.1]*. Thus, user must be in logged-in state for using this grain anlayser.

8.8 Scalable Architecture

MVC (Model View Control) architecture is followed for implementation. Developed grain analyser architecture is scalable enough to deal with new grain and grain varieties. User needs to update only model value, based on that view would be changed. When any new grain varieties are added at that time it is require to add the respective database values for that. This values needs to be updated only once while using it first time.

CHAPTER – 9

Results and Discussions

The development of the standard calibration files to analyse the rice dimensional analysis is the first stage of the process. Various calibration standards have been developed for the detection of broken head, full length, length, width, area and color based sorting. These were tested and have been validated with the known samples. These learning data and measurement is considered as a base and then actual samples are randomly authenticated. Samples including red rice, green rice and foreign elements are also included.

The first stage with image processing is to find the interested regions in the image. Interested regions are related to grain quality. The rest part in the image is considered as a background which needs to be subtracted. The algorithm used for segmentation has parameter which can be considered to identify the minimum length of individual seed. That parameter is configurable, and can be set according to grain sample. This parameter is actually useful for removing noise, but with that little impurity particles can also be removed by setting its value. However rule of thumb needs to be specified, otherwise there is chance of original seed ignorance. Following are different segmented images taken for rice sample PR-21. Fig. 9.1(a) is original sample image and Fig. 9.1(b) and Fig. 9.1(c) are segmented with configurable parameter ***blob.minLength*** whose value is 25 and 15 respectively. In Fig. 9.1(b) we can see that few seeds are ignored as it's considered not of interest because of the insufficient length. If we decrease the value of *blob.min.length* then it will identify mostly all the seeds in grain sample.

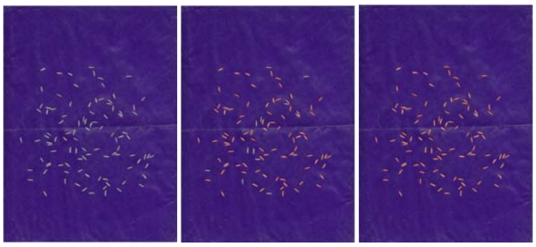


FIGURE 9.1: (a) Original Image (b) Segmented Image (blob.minLength=25) (c) Segmented Image (blob.minLength=15)

Different experiments are carried out for proving the accuracy of developed grain analyser. The testing rice samples are broadly classified based on the following criteria:

Position – Horizontal, Vertical, Crossed

Overlapped, Broken

Color – Black, Green, Red

Whole, Head, Big, Medium, Small

9.1 Overlapped analysis

With this research the seeds were spread over the flat surface while capturing the image. So with that, it is first required to identify and deal with the touching and overlapped kernels. Identification of it is done based on the area covered by the particular blob in the image. If area is outside particular range then it can be identified as overlapped seed. It is require to find mapping relation of it with quality analysis. Fig. 9.2 (a) shows the original image and after segmentation of it we can get the resultant image as in Fig. 9.2 (b). Based on the overlapped identification filters are developed to show them filtered as in Fig. 9.2 (c).

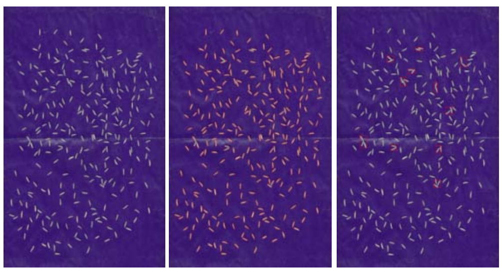


FIGURE 9.2: (a) Original Image (b) Segmented Image (c) Overlapped Filtered Image

Table 9.1 shows the results for the analysis of 25, 50, 100, 200 and more than 200 numbers of seeds are analysed with overlapping and without overlapping.

TABLE 9.1: Overlapped kernel analysis

Grain Sample	Overlapped (Length mm)	No Overlapping (Length mm)	Diff. (+/-)
S1 (25 Seeds)	6.89	6.76	0.13
S2 (50 Seeds)	6.83	6.87	0.04
S3 (100 Seeds)	6.97	6.97	0.00
S4 (200 Seeds)	6.99	6.98	0.01
S5 (Many)	7.00	6.99	0.01

With large numbers of experiments we found that, if overlapped seeds are ignored for analysis by some mechanisms then also rest of the seeds are providing the expected quality results. Length result analysis difference is not more than 0.13mm. Other analysis is, if we increase the numbers of seeds accuracy become better. So if the system will use for huge amount of sample then also consistence results are achieved.

9.2 Size Measurement

Various experiments are carried out for different types of grain. Experiments are carried out for measuring the difference while angular positions are changed and repeatability of the analysis results is checked. Length distributions among grain sample seed is analysed as it is important that the how many different numbers of seeds falling into particular length group category.

9.2.1 Rice grain analysis

Experiments are carried out for measuring the length of rice samples for the variety PR20 Basamati. Out of them few results analysis are discussed here. First 20 seeds's individual length is measured and compared with the manually measured length. For that experiment is done by arranging the rice kernel first horizontally and then by arranging all the rice seeds vertically. This is required to check the length difference while seed's angular position is changed. With this we can prove that, even the same sample is measured repetitively then also the analysis results are same. Same experiment is performed for 50 number of rice seeds to get more accurate results. In addition to horizontal, vertical positions seeds are also arranged in crossed direction for getting better angular position based results. With that we can achieve both *qualitative* and *quantitative* analysis for the grain analyser. Length measurement analyses are also carried out for the broken seeds. To check this, the broken seeds are mixed with normal seeds and analysis is took place.

Below samples are taken for length measurement:

- 20 number of seeds are arranged vertically and then same seeds are arranged in horizontal direction and compared with manual analysis (Table 9.2, Fig. 9.3).
- 50 numbers of seeds are arranged vertical, then horizontal and then same seeds are arranged in crossed direction and compared with manual analysis (Table 9.3, Fig. 9.4).
- 10 number of only broken seeds length measured and compared with manual measurement (Table 9.4, Fig. 9.5).
- Broken seeds mix with normal seeds and length measurement is done - total 15 seeds (Table 9.5, Fig. 9.6).

TABLE 9.2: Vertical and horizontal aligned seeds length comparison with manual measurement (20 seeds)

Rice Id	**M**	**V**	**H**	**Diff. (V-M)**	**Diff. (H-M)**	**Rice Id**	**M**	**V**	**H**	**Diff. (V-M)**	**Diff. (H-M)**
1	6.50	6.22	6.73	-0.28	0.23	**12**	8.06	7.75	-0.31	-0.31	-0.44
2	6.85	6.73	6.86	-0.12	0.01	**13**	8.06	7.75	-0.31	-0.31	-0.19
3	7.37	7.24	7.24	-0.13	-0.13	**14**	8.23	8.13	-0.1	-0.1	-0.23
4	7.61	7.24	7.37	-0.37	-0.24	**15**	8.25	8.25	0.02	0	-0.23
5	7.65	7.49	7.37	-0.16	-0.28	**16**	8.27	8.25	-0.02	-0.02	-0.27
6	7.67	7.49	7.37	-0.18	-0.3	**17**	8.44	8.25	-0.19	-0.19	-0.31
7	7.72	7.62	7.49	-0.1	-0.23	**18**	8.47	8.25	-0.22	-0.22	-0.09
8	7.72	7.75	7.49	0.03	-0.23	**19**	8.6	8.25	-0.35	-0.35	-0.22
9	7.74	7.75	7.49	0.01	-0.25	**20**	8.65	8.51	-0.14	-0.14	-0.01
10	7.82	7.75	7.62	-0.07	-0.2	**Avg.**	**7.88**	**7.72**	**7.68**	**-0.15**	**-0.19**
11	7.85	7.75	7.62	-0.1	-0.23						

* M – Manual, V-Vertical, H-Horizontal, Diff (V-M) – length difference measured vertically and manually, Diff (H-M) – length difference measured horizontally and manually.
Note: all measurement is in mm.

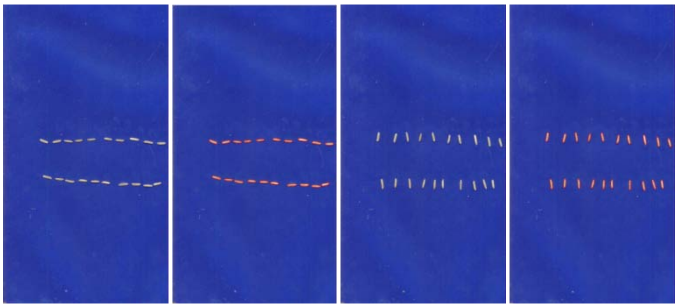


FIGURE 9.3: (a) Original Image – 20 Horizontal (b) Segmented Image – 20 Horizontal (c) Original Image – 20 Vertical (b) Segmented Image – 20 Vertical

FIGURE 9.4: (a) Original Image – 50 Horizontal (b) Segmented Image – 50 Horizontal (c) Original Image – 50 Vertical (d) Segmented Image – 50 Vertical (e) Original Image – 50 Crossed (f) Segmented Image – 50 Crossed

TABLE 9.3: Vertical, horizontal and crossed aligned seeds length comparison with manual measurement (50 seeds)

Rice Id	M	V	H	C	Rice Id	M	V	H	C
1	7.46	7.37	7.37	7.37	**27**	8.19	7.87	7.87	8.13
2	8.06	8.00	7.87	8.13	**28**	7.45	7.24	7.11	7.11
3	7.82	7.87	7.62	6.86	**29**	8.48	8.38	8.38	8.64
4	8.17	8.00	8.38	8.38	**30**	8.5	8.38	8.25	8.51
5	8.52	8.51	8.38	8.51	**31**	8.04	8.00	7.87	7.49
6	8.46	8.25	8.38	8.64	**32**	7.1	7.87	7.62	7.11
7	7.61	7.49	7.49	7.62	**33**	7.41	7.49	7.49	7.37
8	8.51	8.25	8.51	8.25	**34**	7.39	7.37	7.37	7.37
9	7.93	8.00	7.37	7.62	**35**	6.98	6.98	6.86	5.71
10	8.39	8.25	8.38	8.25	**36**	7.94	8.13	7.87	7.87
11	7.76	7.75	7.49	7.75	**37**	7.12	6.35	6.86	6.98
12	7.85	5.97	7.62	7.49	**38**	7.93	7.75	7.75	6.86
13	7.97	7.87	7.62	7.87	**39**	8.38	8.13	8.38	8.51
14	7.87	7.87	7.75	7.75	**40**	6.48	6.22	6.10	6.60
15	7.31	7.11	7.49	7.11	**41**	8.37	8.13	8.25	8.25

16	8.05	8.00	7.75	8.00	**42**	8.44	8.13	8.38	8.13
17	7.73	7.49	7.49	7.62	**43**	8.2	8.25	8.13	5.25
18	7.46	7.11	7.11	7.24	**44**	7.32	7.24	7.24	7.24
19	7.23	7.11	6.98	7.24	**45**	8.45	7.49	8.25	8.51
20	8.3	8.64	8.25	8.38	**46**	7.26	7.37	7.24	7.37
21	7.63	7.37	7.49	7.49	**47**	7.39	7.24	7.11	7.37
22	8.09	7.87	7.87	8.00	**48**	7.25	6.73	6.86	7.24
23	8.48	8.51	8.25	8.38	**49**	8.35	8.25	8.00	8.25
24	6.98	6.73	6.60	6.86	**50**	8.25	8.25	7.87	8.25
25	8.31	8.25	8.13	7.62	**Avg.**	**7.84**	**7.69**	**7.69**	**7.64**
26	7.54	7.37	7.62	7.62	**Diff.**	--	**0.15 (V-M)**	**0.15 (H-M)**	**0.19 (C-M)**

* M – Manual, V-Vertical, H-Horizontal, Diff (V-M) – length difference measured vertically and manually, Diff (H-M) – length difference measured horizontally and manually, Diff (C-M) – length difference measured crossed and manually.
Note: all measurement is in mm.

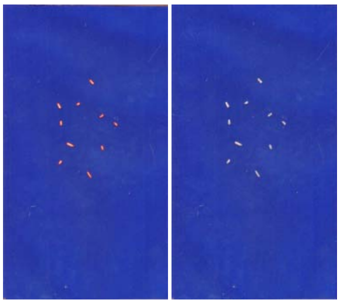


FIGURE 9.5: (a) Original Image - Broken (b) Segmented Image – Broken

TABLE 9.4: Only broken seeds length comparison with manual measurement (10 broken seeds)

Rice Id	M	by GA	Diff
1	4.73	4.83	-0.10
2	3.20	3.05	0.15
3	4.69	4.70	-0.01
4	3.72	3.94	-0.22
5	4.04	3.17	0.87
6	4.12	3.81	0.31
7	4.00	3.94	0.06
8	6.89	6.60	0.29
9	3.95	3.68	0.27
10	6.41	6.35	0.06
Avg.	4.575	4.407	0.168

* M – Manually, byGA – by Grain Analyser, Diff – Difference of length measured manually and by grain analyser.
Note: all measurement is in mm.

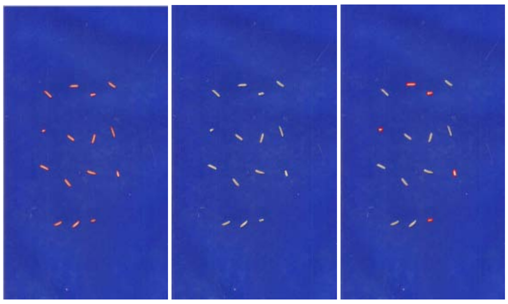


FIGURE 9.6: (a) Original Image - Broken mix (b) Segmented Image – Broken Mix (c) Filtered Image – Broken Mix

TABLE 9.5:Broken mixed seeds length comparison with manual measurement (15 seeds)

Rice Id	M	by GA	Diff
1	8.39	8.64	-0.25
2	7.58	7.75	-0.17
3	4.73	4.70	0.03
4	7.72	7.87	-0.15
5	3.20	3.30	-0.10
6	7.66	7.87	-0.21
7	8.11	8.25	-0.14
8	9.18	9.14	0.04
9	8.44	8.51	-0.07
10	7.99	8.00	-0.01
11	8.32	8.38	-0.06
12	4.69	4.83	-0.14
13	7.78	7.75	0.03
14	7.97	8.75	-0.78
15	3.72	3.94	-0.22
Avg.	**7.0320**	**7.1787**	**- 0.1467**

* M – Manually, byGA – by Grain Analyser, Diff – Difference of length measured manually and by grain analyser.
Note: all measurement is in mm.

For any grain sample's quality measurement, it is require to measure average length of seeds. With above experiments we found that the length has not more than 0.25 mm difference with manual measurement with angular positions changed, which is in standard measurement deviation range for rice standards [Table 9.10].

Above discussed experiments are carried out for proving the average parameters are up to measurement standards. With next, the experiments are carried out to identify the accuracy of the length distributions in the grain sample.

Table 9.6, 9.7 and 9.8 show the difference length measurement analysis and comparison with manual analysis. All samples taken for experiments are containing different number of seeds i.e. 50,125, 150, 175 and 250. In each sample the number of seeds of particular length are identified and compared with manual analysis.

TABLE 9.6: Analysis for 2mm and 3mm kernels

Dimension 2 mm				
No. of kernels	Manual	set1	set2	Accuracy (%)
50	5	5	5	100
125	10	10	10	100
150	5	5	5	100
175	10	10	10	100
250	20	10	10	50
			Avg.	90.00%

Dimension 3 mm				
No. of kernels	Manual	set1	set2	Accuracy (%)
50	30	30	25	91.66
125	20	15	15	75.00
150	30	40	30	83.33
175	20	15	15	75.00
250	30	35	25	83.33
			Avg.	85%

TABLE 9.7:Analysis for 4mm and 5mm kernels

Dimension 4 mm				
No. of kernels	Manual	set1	set2	Accuracy (%)
10	10	10	15	75
30	10	0	10	50
50	20	20	25	100
			Avg.	75.00%

Dimension 5 mm				
No. of kernels	Manual	set1	set2	Accuracy (%)
50	5	5	5	100
125	15	15	15	100
150	5	10	10	50
175	20	20	10	75
250	25	30	30	80
			Avg.	81.00%

TABLE 9.8:Analysis for 6mm and 7mm kernels

Dimension 6 mm				
No. of kernels	Manual	set1	set2	Accuracy (%)
50	30	35	30	92.85
125	25	20	30	80
150	30	30	30	100
175	40	40	40	100
250	60	70	60	91.66
			Avg.	92.90%

Dimension 7 mm				
No. of kernels	Manual	set1	set2	Accuracy (%)
50	70	65	65	92.85
125	55	60	50	90.9
150	70	65	65	92.85
175	80	75	85	93.75
250	95	85	100	92.1
			Avg.	92.49%

With length measurement analysis we can get overall more than 85% accuracy.

9.2.2 Other grain analysis

Various experiments are carried out for other types of grain. Length and width of wheat, green gram, white lentils, green gram lentils, chickpeas, sesame and fenugreek are analysed and results are compared with manual analysis. For every grain three different samples (S1, S2, S3) are taken more analysis. Analyses for different grain varieties are as shown in Table 9.9.

TABLE 9.9: Different Grain Analysis Results

Grain Type	Manual (Average Length mm)						By Grain Analyser (Average Length mm)						Difference (+ / -)					
	S1		S2		S3		S1		S2		S3		S1		S2		S3	
	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
Wheat	6.50	3.82	6.45	3.80	6.47	3.85	6.39	4.02	6.30	4.02	6.33	4.01	0.11	0.20	0.12	0.22	0.14	0.16
Green gram	4.20	3.56	4.21	3.59	4.17	3.67	4.09	3.76	4.07	3.76	4.01	3.74	0.11	0.20	0.20	0.17	0.16	0.07
White gramlentils	3.91	3.60	3.95	3.70	3.85	3.60	4.01	3.74	4.10	3.80	4.20	3.77	0.10	0.14	0.25	0.10	0.35	0.17
Green gram lentils	4.35	3.55	4.31	3.49	4.40	3.45	4.12	3.71	4.06	3.61	4.01	3.56	0.23	0.16	0.30	0.12	0.39	0.11
Chickpeas	7.84	6.45	7.80	6.48	7.95	6.52	7.94	6.64	7.99	6.72	7.92	6.71	0.10	0.19	0.12	0.24	0.03	0.19
Sesame	2.80	2.0	2.82	1.98	2.85	1.99	2.94	2.14	2.95	2.15	2.96	2.15	0.14	0.14	0.14	0.17	0.11	0.16
Fenugreek	3.95	3.45	3.98	3.41	3.93	3.39	4.09	3.50	4.07	3.51	4.03	3.49	0.14	0.05	0.05	0.10	0.10	0.10

With experiment we found that for all other types of grain also the maximum difference found is 0.40 mm. Moreover the length and width difference was not more than 0.18 mm for the samples which are identified by grain analyser.

9.2.3 Comparison with other grain analyses

With different grain analysers techniques the length measurement accuracy are provided as shown in table below:

TABLE 9.10: Different Grain Analysis Techniques Length Standards Deviation

Grain Analyser	Length Standard Deviation (mm)
Seed Count (Armstrong, et al. 2005)(SeedCount-Ltd. 2006)	0.29-0.41
Shaker Table (Lloyd, Cnossen and Siebenmorgen 2001)	0.70-0.88
Grain Check (Lloyd, Cnossen and Siebenmorgen 2001)	0.40-0.80
FGIS (Lloyd, Cnossen and Siebenmorgen 2001)	0.20-0.84
Matlab(Mandal, Roy and Tanna 2012)	0.30-0.80

DIA (Hobson, Carter and Yan, Characterisation and identification of rice grains through digital image analysis 2007)	0.24-0.55
GRAIN QUALITY EVA (Broken) (Bhonsle and Sellappan 2010)	0.7-1.63
Image Processing Techniques for Grading (Verma 2010)	0.2-0.8

9.3 Repeatability of Analysis Results

To check the repeatability of analysis results experiments are carried out for measuring same grain sample with many numbers of iteration. Analysis results are as shown in Table 9.11.

TABLE 9.11: Repeatability Analysis

Basamati Rice	Length (mm)
S1	7.02
S2	7.02
S3	6.99
S4	7.01
S5	7.00

With various experiments we found that, if same grain sample is analysed many times then we can get expected consistent quality results. The length difference for all measured sample is not more than +/- 0.03 mm.

9.4 Image Resolution Analysis

With various experiments are carried out for identifying resolution based variance in analysis results. Jirasal Lajawab, Veer, Sadhu, Alakatta, ParimalPonni and Kohinoor Basamati varieties length and width are analysed for 75 dpi, 100 dpi, 150 dpi, 200 dpi, 300 dpi, 400 dpi and 600 dpi. Analysis results are as shown in Table 9.12.

TABLE 9.12: Image Resolution Analysis

	Jirasal Ponni		Lajawab		Veer		Sadhu		Alakatta		Parimal Ponni		Kohinoor	
Sr.No.	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**
Manual Measurement														
1	5.91	2.11	7.20	2.08	7.95	1.85	7.92	2.01	7.54	2.11	3.94	2.20	7.37	1.95
2	6.21	1.92	7.25	1.98	8.01	2.30	7.50	1.81	9.01	2.09	6.20	2.37	7.07	2.12
3	4.88	1.82	7.45	1.91	8.00	2.11	7.05	2.11	8.82	2.09	5.60	2.03	7.87	2.20
4	5.42	2.01	8.52	1.90	8.15	1.89	6.82	2.09	8.89	2.30	6.24	2.54	7.28	1.95
5	5.41	2.02	7.28	1.87	4.95	2.47	6.81	2.10	7.95	2.11	5.84	2.46	7.00	2.03
6	4.88	1.94	7.51	1.93	6.91	1.90	7.21	1.81	7.91	2.17	6.89	2.79	7.03	2.12
7	5.11	1.91	6.89	2.04	7.88	2.12	7.91	1.99	7.51	2.21	5.50	2.54	7.2	2.03
8	5.22	1.90	7.15	1.90	7.92	2.15	7.81	1.51	7.25	2.15	4.05	2.40	6.6	2.2
9	5.11	1.90	8.91	1.93	7.92	1.60	8.09	2.00	7.56	2.18	6.06	2.62	6.77	2.03
10	5.17	2.02	7.35	2.12	8.45	1.89	7.30	1.55	7.64	2.12	3.95	2.20	7.45	2.11
11	5.08	1.90	7.88	2.10	7.93	2.13	8.05	1.81	7.23	2.23	6.11	2.37	7.87	2.03
12	4.10	2.08	8.10	2.06	8.24	1.95	7.65	2.12	7.62	1.82	5.27	2.62	6.86	2.07
13	4.91	1.99	8.48	1.96	8.26	2.35	7.90	1.91	7.47	2.12	6.75	2.46	7.5	2.03
14	3.62	1.80	7.44	2.01	7.88	2.16	7.21	2.12	7.41	2.20	6.50	2.12	7.28	1.98
15	4.89	2.11	6.89	1.60	7.90	2.10	7.05	1.57	7.77	2.15	4.85	2.54	6.94	2.03
16	4.50	1.88	6.85	2.10	8.05	2.05	7.89	2.08	7.47	2.16	5.80	1.69	6.26	2.03
17	4.10	1.90	7.00	1.91	6.88	2.30	7.47	2.07	7.80	2.18	5.54	2.37	6.94	2.30
18	4.50	2.01	7.20	2.02	6.49	2.25	6.78	2.10	7.90	2.17	5.57	2.40	6.49	1.95
19	4.81	2.12	7.20	1.65	7.50	1.99	7.79	1.89	7.58	2.18	5.59	2.54	6.69	1.93
20	5.10	2.10	7.39	1.91	8.02	2.47	7.82	2.09	7.20	1.90	6.13	2.37	6.77	1.95
AVG (20)	4.95	1.97	7.50	1.95	7.66	2.10	7.50	1.94	7.78	2.13	5.62	2.39	7.06	2.06
AVG (many)	5.05	2.29	7.45	2.17	7.71	2.17	7.28	2.05	7.76	2.22	5.30	5.45	6.99	2.03
Grain Analyser Measurement														
200 dpi (20)	5.04	2.09	7.66	2.15	7.52	2.21	7.48	2.14	7.70	2.24	5.75	2.46	6.87	2.13
300 dpi (20)	5.18	2.08	7.86	2.08	7.55	2.12	7.36	2.05	7.52	2.20	5.52	2.37	7.08	2.09
75 dpi (many)	4.90	2.78	7.92	2.61	8.27	2.65	7.80	2.55	8.29	2.70	5.16	2.92	6.59	2.55
100 dpi (many)	4.92	2.56	7.19	2.33	7.22	2.40	6.96	2.27	7.42	2.46	5.16	2.73	6.71	2.36
150 dpi (many)	5.01	2.42	7.40	2.19	7.53	2.31	7.18	2.19	7.73	2.36	5.25	2.60	6.98	2.20
200 dpi (many)	5.07	2.32	7.53	2.18	7.70	2.21	7.22	2.09	7.80	2.26	5.30	2.50	7.03	2.10
300 dpi (many)	5.10	2.25	7.42	2.16	7.74	2.14	7.33	2.03	7.78	2.19	5.28	2.43	7.01	2.05
400 dpi (many)	5.13	2.19	7.30	2.04	7.77	2.06	7.30	1.95	7.60	2.12	5.29	2.36	6.87	1.96
600 dpi (many)	4.90	2.15	6.95	2.05	7.26	2.09	6.86	1.94	7.40	2.09	5.11	2.36	6.60	1.97

Based on experiments we can conclude that 300 dpi images give the expected quality results.

9.5 Color Calibration and Measurement

Techniques are developed to identify and filter the colored seed. With this color classification we can identify immature seeds like red, green, yellow, brown and paddy. Normal seeds are mixed with the red colored seeds (Fig. 9.7 (a)) and then with grain analyser we filtered them (Fig. 9.7 (b)). A same experiment is also carried out for green colored seeds and depicted in Fig. 9.8.

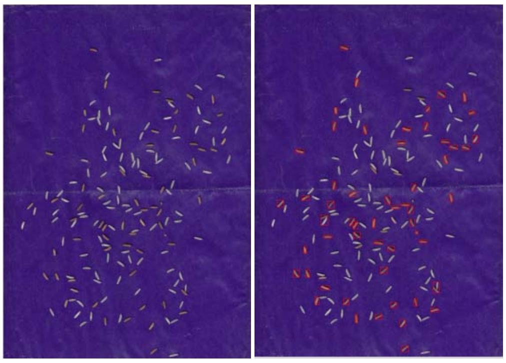


FIGURE 9.7: (a) Normal Image (b) Red Filtered Image

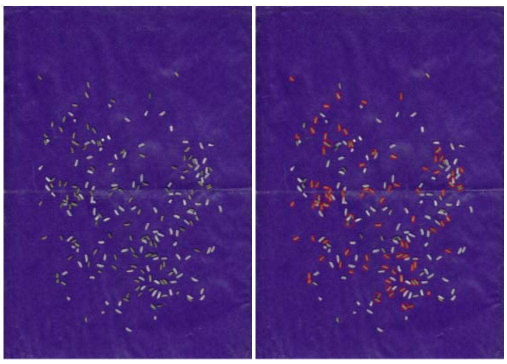


FIGURE 9.8: (a) Normal Image (b) Green Filtered Image

To identify the color seed, it is first required to generate calibration file. Calibration file is required because different organisations have their own naming criteria. Therefore it is required to configure the grain analyser. Generated calibration file acts as a predefined configuration for grain analyser. Experiments are carried out for authenticating the accuracy of the grain analyser with the different generated calibration files.

Four rice samples are taken as training data set as given below:

- Only red colored rice (20 seeds)
- Only green colored rice (20 seeds)
- Only yellow colored rice (20 seeds)
- Only black colored rice (20 seeds)
- Only white colored rice (20 seeds)

For every sample, calibration file is generated containing all possible color of each seed. After generating the individual calibration files for the RGB combinations values are combined and single calibration file is generated. Experiment is repeated for second approach and calibration files are generated. Total two calibration files are generated, approach-I [*ref. section 5.4.1]* calibration file and approach-II *[ref. section 5.4.2]* calibration file. With both calibration files following rice samples are analysed and results are carried out. Samples are divided into two groups from top level.

Group I: *Colored rice seeds are same, which are used for generating calibration files (trained data is used).*

Group II: *Colored rice seeds are different and not used earlier for generating calibration file (trained data is not used).*

For above both approaches below types of samples are prepared and analysed and results are depicted in Table 9.13, Table 9.14, Table 9.15 and Table 9.16.

- White – red colored mixed rice (20 white, 20 red seeds)
- White – yellow colored mixed rice (20 white, 20 yellow seeds)
- White – green colored mixed rice (20 white, 20 green seeds)
- White – black colored mixed rice (20 white, 20 black seeds)
- Red – yellow – green colored mixed rice (20 red, 20 yellow, 20 green seeds)
- Green – black – red colored mixed rice (20 green, 20 black, 20 red seeds)

- White – red – yellow – green colored mixed rice. (20 white, 20 red, 20 yellow, 20 green seeds)

TABLE 9.13: Seeds identified by approach-I, group-I

Color / Sample	White	Red	Yellow	Green	black	NI	Accuracy (%)
S1	30	30	0	0	0	0	100%
S2	29	0	30	0	0	1	98%
S3	30	0	0	30	0	0	100%
S4	29	0	0	0	30	1	98%
S5	0	29	30	29	0	2	98%
S6	0	29	0	30	30	1	99%
S7	29	30	29	29	0	3	97%

* NI – Not identified by grain analyser. S1-S7 – Sample range
Note: All numbers shows number of seeds of particular color group.

TABLE 9.14: Seeds identified by approach-II, group-I

Color / Sample	White	Red	Yellow	Green	black	NI	Accuracy (%)
S1	30	30	0	0	0	0	100%
S2	29	0	30	0	0	1	98%
S3	30	0	0	30	0	0	100%
S4	28	0	0	0	29	3	95%
S5	0	29	30	29	0	2	98%
S6	0	29	0	30	30	1	99%
S7	29	30	28	28	0	5	96%

* NI – Not identified by grain analyser. S1-S7 – Sample range
Note: All numbers shows number of seeds of particular color group.

TABLE 9.15: Seeds identified by approach-I, group-II

Color / Sample	White	Red	Yellow	Green	black	NI	Accuracy (%)
S1	27	27	0	0	0	6	90%
S2	30	0	27	0	0	3	95%
S3	30	0	0	30	0	0	100%
S4	28	0	0	0	24	8	87%
S5	0	30	27	27	0	6	93%
S6	0	30	0	30	30	0	100%
S7	30	27	29	28	0	6	95%

* NI – Not identified by grain analyser. S1-S7 – Sample range
Note: All numbers shows number of seeds of particular color group.

TABLE 9.16: Seeds identified by approach-II, group-II

Color / Sample	White	Red	Yellow	Green	black	NI	Accuracy (%)
S1	27	26	0	0	0	6	88%
S2	28	0	27	0	0	8	92%
S3	30	0	0	30	0	0	100%
S4	28	0	0	0	23	9	85%
S5	0	29	27	27	0	6	90%
S6	0	30	0	30	30	0	100%
S7	27	27	28	29	0	9	92%

* NI – Not identified by grain analyser. S1-S7 – Sample range
Note: All numbers shows number of seeds of particular color group.

With this experiment we conclude that, if rice seeds which are used for preparing calibration files (trained data) are used for actual analysis then it shows around 95% accurate color classification results with both the approaches. But if seeds are different than the seeds which are used for generating calibration file then it shows more than 90% accuracy. It is because of the few seeds colors (RGB combinations) were not available while generating calibration file. If we add the not identified RGB color combination to particular group and analyses the same sample again then we are able to achieve 100% accuracy. If we don't want to do repetitive process of adding RGB combinations then we can use the range for that particular color. Range includes the colors which are having nearer RGB combinations to it. This methodology is explained in deep with foreign element identification in next section.

9.6 Foreign Element Identification

Experiments are carried out for identifying non quality elements (foreign elements) from the rice sample based on color. Foreign elements (FE) can have different color than regular seeds. So FE can be distinguished from regular seeds based on color combinations. For all FE it is required to create RGB color array with machine learning, which is given as input data to imaging software for color classification. To prepare RGB color array for FE, only FEs are taken for analysis. RGB combination array is prepared based on analysis. This array group is applied as input while analysing actual grain sample and based on matching we can distinguish the FEs. Learning elements (LEs) are the subset of all foreign elements which are used for preparing FE RGB color array. Number of learning elements can be increased for covering big range of foreign elements RGB combinations.

For preparing RGB array experiments are carried out with 5 learning elements LE (5) and 10 learning elements LE (10). Samples are taken based on different combinations as below:

- 5 FEs (3 Samples)
- 10 FEs (3 Samples)
- 15 FEs (3 Samples)
- 20 FEs (1 Samples)
- 25 FEs (1 Samples)
- 30 FEs (1 Samples)
- 40 FEs (1 Sample)

We did experiment for identifying foreign elements. To classify foreign elements, it is require mapping its RGB combination with predefined measurement. For that we tried two different approaches mentioned below:

Approach 1: RGB color classification is done based on the actual value of comparison with RGB composition array *(Table* 9.17).

Approach 2: RGB color classification is done based on the range comparison with RGB composition array (*Table 9.18).*

TABLE 9.17: Foreign elements identification with 5 / 10 learning elements approach – I

	Identified		Overlapped Not Identified		Wrongly Identified		Accuracy (%)	
FE	**LE (5)**	**LE (10)**	**LE (5)**	**LE (10)**	**LE (5)**	**LE (10)**	**LE (5)**	**LE (10)**
5	2	2	3	3	0	0	40.00	40.00
	2	2	3	3	0	0	40.00	40.00
	3	5	2	0	0	0	60.00	100.00
10	4	5	6	5	0	0	40.00	50.00
	3	5	7	5	0	0	30.00	50.00
	5	6	5	4	0	0	50.00	60.00
15	3	8	12	7	0	0	20.00	53.33
	5	10	10	5	0	0	33.33	66.67
	5	11	10	4	0	0	33.33	73.33
20	7	14	13	6	0	0	35.00	70.00
25	10	17	15	8	0	0	40.00	68.00
30	14	18	16	12	0	0	46.67	60.00
40	15	22	25	18	0	0	37.50	55.00

* FE – Foreign Element, LE – Learning Element

TABLE 9.18: Foreign elements identification with 5 / 10 learning elements approach - II

	Identified		Overlapped Not Identified		Wrongly Identified		Accuracy (%)	
FE	**LE (5)**	**LE (10)**	**LE (5)**	**LE (10)**	**LE (5)**	**LE (10)**	**LE (5)**	**LE (10)**
5	4	4	1	1	0	0	80.00	80.00
	3	3	2	2	0	0	60.00	60.00
	5	5	0	0	0	0	100.00	100.00
10	7	7	3	3	0	0	70.00	70.00
	8	8	2	2	0	0	80.00	80.00
	8	8	2	2	0	0	80.00	80.00
15	15	15	0	0	0	0	100.00	100.00
	12	12	3	3	0	0	80.00	80.00
	14	14	1	1	0	0	93.33	93.33
20	19	19	1	1	0	0	95.00	95.00
25	22	22	3	3	0	0	88.00	88.00
30	28	28	2	3	0	0	93.33	93.33
40	36	35	4	5	0	0	90.00	87.50

* FE – Foreign Element, LE – Learning Element

With these experiments we conclude that, we can achieve more than 85% accuracy in identifying the foreign elements. However, for this accuracy overlapped seeds are also considered. But if overlapped seeds are ignored, then the average accuracy can be achieved more than it. Moreover, there is no any wrongly identified foreign element, which means actual seed is not considered as foreign element any time. With approach 2, better quality results are achieved. As the exact RGB combination will not be same with different iteration while measuring various samples with similar kind of impurities.

CHAPTER – 10

Conclusions and Future Enhancements

10.1 Original contribution by the thesis.

The presented research work addresses the need for farmers as well as other stake holders such as distributers, exporters, including consumers to get the true economic value of rice based on its dimensional aspect like color, length, broken head, chalkiness etc. The research proposes the image based rice kernel analysis even in the case of online sample analysis. The rice distribution, on the tray, need not be in the properly arranged structure. The presented approach can easily handle uneven arrangement of rice kernels. The novel contribution and achievements of this thesis are:

- A simple yet fast and powerful technique for analyzing grain which can be used for analyzing grain in mass instead of a very small sample used in current approaches

- Techniques for size measurement and broken grain analysis adopting various international standards

- A novel technique for color calibration is developed to introduce subjective color classification by various groups/agencies/organisations.

- Techniques for providing individual kernel measurement and average parameters of grain sample leading to details statistical analysis if required.

- Developed a common platform for grain analysis, which can be used for different type of grain types and its varieties.

- Desktop, web based and mobile based systems.

- Statistical Analysis - Graphical statistical analysis and text output is also simultaneously generated indicating number of rice grain in each category with their individual parameters.

10.2 Features Comparison of Developed Grain Analyser with Conventional Offline / Online Image Based Grain Analyser

Table 10.1 shows the comparison of an offline and online image based grain analyser's features with developed grain analyser.

TABLE 10.1: Comparison of developed grain analyser with conventional grain analysers

	Seed Count 324 (Armstrong, et al. 2005)(SeedCount Australasia Pty Ltd n.d.)	Image acquisition system (Guzman and Peralta 2008)	Rice Quality Analyser RN300 (Rice Quality Analyzer – Model RN 300 manual by Kett (Science of sensing) n.d.)	HRY GrainCheck310 (Wang, et al. 2005)	Automatic grain quality inspection (Wan and Fangquan 2002)	Developed Grain Analyser
Offline/Online	Offline	Offline	Offline	Online	Online	Offline + Online
Chalkiness/ Vitreousness	No	No	No	No	No	Yes
Predetermined Matrix or slotted tray	Yes	Yes	Yes	Yes	Yes	No
Camera Angle Dependency	Yes	Yes	No	Yes	Yes	NA*
Light Source Dependency	Yes	Yes	Yes	Yes	Yes	Yes
Light Transmission	No	No	Yes	Yes	No	No
Consume more static sample preparation time	Yes	Yes	Yes	No	No	No
Grain should be fit in grain slot	Yes	Yes	Yes	NS*	Yes	No
Time	NS*	NS*	1 Sample / 24 Sec.	NS*	1200 Kernels/Min	1 Sample / 15 Sec.
Grain	Rice	Rice	Rice	Wheat	Rice	Rice, wheat & others
Maximum no. of Kernels	1350	110	1148	50	24	Depends on Scanner
Technologies	NS	CIAS 2.0, MS Excel, Neural Network	Quality Scan, Matlab, Neural Network	Grain check	C Visual Basic	VB.Net, C#.Net, SQL Server, FTP Server
Vibration	No	No	No	Yes	No	No

NS* – Not Specified, NA* – Not Applicable

10.3 Achievements with respect to objectives

The test results summarized as an achievement of the proposed algorithm. We can analyse grain sample with new technology which doesn't depend upon predetermined matrix i.e. slotted tray. This analyser can be calibrated for different measured parameters according to organisation standards. With this work, we can characterize various attributes of rice like physical characteristics as well as color based segregation. It provides the details regarding total number of overlapped and broken seeds along with chalkiness of the seed.

With the discussed approach color calibration and sorting can be done effectively for different grains by considering different organisations standards. We can use this analyser technique for dealing with different type of rice varieties and other grain varieties. Dependency on predetermined matrix, while preparing sample is removed. It has removed some deficiencies in offline/online image based grain analysers. Dependency on number of kernels is removed, by eliminating the fix sized grid. The performance results of our implementation agree with the theoretical analysis. It gives more than 90% accuracy in classification, as customisation is done by end-users only. The repeatability and reproducibility of the proposed algorithm has been very high throughout the wide spectrum of different varieties of kernels. New calibration file can be generated for the new grain type and grain varieties introduced. One time effort needs to be put for machine learning, then after same calibration file can give consistent result for the measurement of same type grain samples. With this technology we can measure individual as well average parameters of grain kernels, and get the graphical analysis of the data. The algorithm has been validated with very high repeatability and accuracy against the conventional techniques at the research labs.

10.4 Future Enhancement

Future enhancement and scope related to the research are:

- Different types of grain and its varieties may be added for which detail analysis related to accuracy and efficacy may be carried out.

- Scanner is used for experiment purpose which can be replaced with conveyor belt with vibration mechanism using proper hardware.

- Instead of identifying seed color as whole, percentage distributions of a color or color group can be considered which is similar to the determination of chalkiness using white color.
- For capturing image CCD cameras or even IP cameras can be used with minor tuning of configuration parameters.

10.5 Conclusion

The image processing based grain sorting machines available in the market suffer from poor online accuracy. The current techniques are also not suitable for analysing gains in large amount. Also the literature reviewed reflects that the validation of the accuracy of sorting is accomplished using conventional human visual sorting technique. The research reviewed fix number of heterogeneous group of kernels upon which the accuracy has been derived. The technique suggested here adds the feature with increased accuracy of processing the large amount of sample kernels online.

Also the instruments available in the market do not allow the user to define his own calibration standards especially for a color based sorting. Based on geographical distribution, this feature is essential to be provided to the end user. The feature of self-calibration provides the user an added functionality and wide scope of acceptance across the globe.

With the discussed approach color calibration and sorting can be done effectively for different grains by considering different organisations' standards. It gives more than 90% accuracy, as customisation is done by end-users only. New calibration file can be generated for the new grain type and grain varieties introduced. One time effort needs to be put for machine learning, then after same calibration file can give consistent result for the measurement of same type grain samples.

With the discussed approaches, foreign elements identification and classification can be done effectively based on RGB color combinations. It gives more than 80% accuracy, as customisation is done by end-users only. Different calibration files can be generated for different varieties of grain. Same imaging setup and same algorithmic approach can be also used for different type of grains. One time effort needs to be put for machine learning, then after same calibration file can give consistent result for the measurement of same type grain samples.

Grain analyser provides facility of measuring many parameters which can be useful for identifying quality of grain sample. Efforts can be made for adding more and more standards to make it generalize. Different grain types and varieties can be added for future work.

Publication List

1. Mihir. N. Dudhrejia, Chetan B. Bhatt and Mehul K. Shah,*“Unexplored Idea to Examine Grain Quality by Utilizing Image Processing Intelligence”*, International Journal of Computer Science and Engineering, Volume 6, Issue 1, Pages 67-78, 2016.

2. Mihir. N. Dudhrejia, Chetan B. Bhatt and Mehul K. Shah,*“Size Measurement and Color Calibration in Image Based Grain Examining”*, International Journal of Advance Research in Computer Science And Management Studies, Volume 4, Issue 11, Pages 39-50, 2016.

3. Mihir. N. Dudhrejia and Chetan B. Bhatt *“Non-destructive foreign element examining for rice quality inspection”*, International Journal of Biology & Today's World - Special Issue On: Role of IT in Bioinformatics and Neuroinformatics. (Accepted)

List of References

All India Rice Exporters Association . All India Rice Exporters Association . 2017. http://www.airea.net/page/95/standards-for-basmati-rice# (accessed 03 25, 2017).

"AForge Imaging Library." *AForge Imaging Library.* 2017.

Agmarknet-Maize. Directorate of Marketing & Inspection (DMI), Ministry of Agriculture and Farmers Welfare GOI. 2016. http://agmarknet.nic.in/Maize_manual.htm (accessed 4 5, 2017).

"Agmark-Wheat." *http://agmarknet.nic.in/.* Directorate of Marketing & Inspection (DMI), Ministry of Agriculture and Farmers Welfare GOI. 2016. http://agmarknet.nic.in/Wheat_manual.htm (accessed 4 6, 2017).

Agustin, Oliver C, and Byung-Joo Oh. "Automatic Milled Rice Quality Evaluation by Image Analysis." 7, no. 3 (2009): 87-94.

Amerah, AM, V Ravindran, RG Lentle, and DG Thomas. "Feed particle size: Implications on the digestion and performance of poultry." *World's Poultry Science Journal* (Cambridge Univ Press) 63, no. 03 (2007): 439-455.

Armstrong, BG, GP Aldred, TA Armstrong, AB Blakeney, and LG Lewin. "Measuring rice grain dimensions with an image analyser." *Quest* 2 (2005): 2-35.

"ARSO : ARS 464 (English) : Milled Rice Specification." *The African Organisation for Standardisation: ARS 464 (2012) (English): Milled rice_Specification.* 2012.

Awad, T.S., H.A. Moharram, O.E. Shaltout, D. Asker, and M.M. Youssef. "Applications of ultrasound in analysis, processing and quality control of food: A review ." *Food Research International* 48, no. 2 (2012): 410-427.

Bautista, RC, TJ Siebenmorgen, and PA Counce. "Rice Kernel Chalkiness and Milling Quality Relationship of Selected Cultivars." 2012.

Behnke, Keith C. "Factors influencing pellet quality." *Feed Tech* 5, no. 4 (2001): 19-22.

Bellon, Vacronique, Jean Louis Vigneau, and Francis Sacvila. "Infrared and near-infrared technology for the food industry and agricultural uses: on-line applications." *Food Control* 5, no. 1 (1994): 21-27.

Bellon, Vacronique, Jean Louis Vigneau, and Francis Sacvila. "Infrared and near-infrared technology for the food industry and agricultural uses: on-line applications." *Food Control* 5, no. 1 (1994): 21-27.

Bhonsle, Shilpa J, and Krishnan Sellappan. “Grain quality evaluation of traditionally cultivated rice varieties of Goa, India.” *Recent Research in science and technology* 2, no. 6 (2010).

Borges, Endler Marcel, Jane Mary Lafayette Neves Gelinski, Vanessa Cristina de Oliveira Souza, Fernando Barbosa Jr, and Bruno Lemos Batista. “Monitoring the authenticity of organic rice via chemometric analysis of elemental data.” *Food Research International* (Elsevier) 77 (2015): 299-309.

Carloni, Elisa, et al. “Validation and application of a quantitative real-time \{PCR\} assay to detect common wheat adulteration of durum wheat for pasta production .” *Food Chemistry* , 2016: - .

Casazza, Anna Paola, Caterina Morcia, Elena Ponzoni, Floriana Gavazzi, Stefano Benedettelli, and Diego Breviario. “A reliable assay for the detection of soft wheat adulteration in Italian pasta is based on the use of new \{DNA\} molecular markers capable of discriminating between Triticum aestivum and Triticum durum .” *Journal of Cereal Science* 56, no. 3 (2012): 733-740.

Chiang, Kung-Yuh, Chun-Kai Liao, and Cheng-Han Lu. “The effects of prepared iron-based catalyst on the energy yield in gasification of rice straw .” *International Journal of Hydrogen Energy* 41, no. 46 (2016): 21747-21754.

CME315 Soil Mechanics Laboratory - Chicago. 2015. http://cemmlab.webhost.uic.edu/Experiment%206-Grain%20Size%20Analysis.pdf (accessed 4 8, 2017).

Cnossen, AG, TJ Siebenmorgen, and W Yang. “Evaluation of two methods for separating head rice from brokens for head rice yield determination.” *Proc. 2000 Rice Technical Working Group Conference.* 2000.

Cocchi, Marina, Caterina Durante, Giorgia Foca, Andrea Marchetti, Lorenzo Tassi, and Alessandro Ulrici. “Durum wheat adulteration detection by \{NIR\} spectroscopy multivariate calibration .” *Talanta* 68, no. 5 (2006): 1505-1511.

“Codex Alimentarius.” Food and Agriculture Organisation of the United Nations. 2016. http://www.fao.org/gsfaonline/docs/CXS_192e.pdf (accessed January 5, 2017).

“CODEX STAN 198-1995.” 2016. www.fao.org/input/download/standards/61/CXS_198e.pdf (accessed 4 6, 2017).

“Codex Standard for Rice: CODEX STAN 198-1995.” *Codex Standard for Rice: CODEX STAN 198-1995.* 1995.

“DFPD.” *http://dfpd.nic.in/.* Department of Food & Public Distribution. 1 9 2014. http://dfpd.nic.in/writereaddata/images/pdf/sra-010914.pdf (accessed 3 25, 2017).

DMI. http://dmi.gov.in/GradesStandard.aspx. 2016. http://agmarknet.nic.in/agm_std1.htm (accessed 4 6, 2017).

Dutta, Malay Kishore, Namita Sengar, Narayan Kamble, Kaushik Banerjee, Navroj Minhas, and Biplab Sarkar. "Image processing based technique for classification of fish quality after cypermethrine exposure." *LWT-Food Science and Technology* (Academic Press) 68 (2016): 408-417.

Elleuch, Mohamed, Souhail Besbes, Olivier Roiseux, Christophe Blecker, and Hamadi Attia. "Quality characteristics of sesame seeds and by-products." *Food Chemistry* (Elsevier) 103, no. 2 (2007): 641-650.

Exporters India. Exporters India. 2017. http://www.exportersindia.com/indian-suppliers/rice.htm (accessed 03 25, 2017).

F., Porikli. "Inter-Camera Color Calibration by Correlation Model Function." 3 (2004): 133-136.

Facco, Pierantonio, Andrea Masiero, and Alessandro Beghi. "Advances on multivariate image analysis for product quality monitoring ." *Journal of Process Control* 23, no. 1 (2013): 89-98.

"FAD16 10730_12092016." *http://www.bis.org.in.* Beauro of Indian Standards. 12 9 2016. http://www.bis.org.in/sf/fad/FAD16(10730)_12092016.pdf (accessed 4 5, 2017).

"FAO United Nations." *Food and Agriculture Organisation of United Nations.* 2015. http://www.fao.org/docrep/x5048e/x5048E02.htm (accessed 3 9, 2017).

Garcia-Maraver, Angela, and Manuel Carpio. "Factors Affecting Pellet Quality." *WIT Transactions on State-of-the-art in Science and Engineering* (WIT Press) 85 (2015): 21-35.

Grain and Seed analysis - ASDInc - PANalytical. 2017. https://www.asdi.com/solutions/agriculture/grain-and-seed-analysis (accessed 4 6, 2017).

Grain Inspection Packers and Stockyards Administrationhttps://www.gipsa.usda.gov/fgis/standards/ricestandards.pdf

Grain-Size-Analysis.aspx. SGS. http://www.sgs.com.au/en-GB/Oil-Gas/Upstream/Unconventional-Resources/Oil-Sands/Grain-Size-Analysis.aspx (accessed 4 8, 2017).

Guangrong, Liu. "Detection of Chalk Degree of Rice Based on Image Processing." *Intelligence Science and Information Engineering (ISIE), 2011 International Conference on.* 2011. 515-518.

Guzman, Jose D, and Engelbert K Peralta. "Classification of Philippine rice grains using machine vision and artificial neural networks." *World conference on agricultural information and IT, Tokyo, Japan.* 2008. 24-27.

“Haifa.” *Haifa.* Haifa. 2017. http://www.haifa-group.com/knowledge_center/crop_guides/rice/growing_rice/#{B93AFFF2-77EC-4E1E-BCEB-61521F430B06} (accessed 3 25, 2017).

Hobson, David M, Robert M Carter, and Yong Yan. “Characterisation and identification of rice grains through digital image analysis.” *Instrumentation and Measurement Technology Conference Proceedings, 2007. IMTC 2007. IEEE.* 2007. 1-5.

—. “Characterisation and identification of rice grains through digital image analysis.” *Instrumentation and Measurement Technology Conference Proceedings, 2007. IMTC 2007. IEEE.* 2007. 1-5.

Huang, Shuangping, Long Qi, Xu Ma, Kunnan Xue, Wenjuan Wang, and Xiaoyuan Zhu. “Hyperspectral image analysis based on BoSW model for rice panicle blast grading .” *Computers and Electronics in Agriculture* 118 (2015): 167-178.

“Intenational Financial Corporation.” 2014. (accessed 2017).

“International rice research institute.” *International rice research institute.* 2006.

“IRRI - Rice Knowledge Bank.” 2016. http://www.knowledgebank.irri.org/index.php?option=com_zoo&task=item&item_id=1124&Itemid=822.

IRRI. IRRI. 2017. http://irri.org/component/itpgooglesearch/search?gsquery=standard (accessed 03 25, 2017).

Jiang, Zaixing, and Li'an Liu. “A pretreatment method for grain size analysis of red mudstones.” *Sedimentary Geology* (Elsevier) 241, no. 1 (2011): 13-21.

Jinorose, Maturada, Somkiat Prachayawarakorn, and Somchart Soponronnarit. “A novel image-analysis based approach to evaluate some physicochemical and cooking properties of rice kernels .” *Journal of Food Engineering* 124 (2014): 184-190.

Katherine Leon, Domingo Mery, Franco Pedreschi Jorge Leon. “Color measurement in L*a*b* units from RGB digital images.” 39 (2006): 1084–1091.

Kaur, Harpreet, and Baljit Singh. “Classification and grading rice using multi-class svm.” *International Journal of Scientific and Research Publications (IJSRP)* 3, no. 4 (2013).

Kayavlon. *Kayavlon Impex Pvt. Ltd.* Kayavlon Impex Pvt. Ltd. 2017. http://www.kayavlon.com/rice-mill-exporter.htm (accessed 3 25, 2017).

“Kett – RN300.” 2009. https://www.kett.com/files/brrn300.pdf.

Kun Li, Qionghai Dai, Wenli Xu. “High quality color calibration for multi-camera systems with an omnidirectional color checker.” 2010: 1026-1029.

Kuo, Tzu-Yi, Chia-Lin Chung, Szu-Yu Chen, Heng-An Lin, and Yan-Fu Kuo. "Identifying rice grains using image analysis and sparse-representation-based classification ." *Computers and Electronics in Agriculture* 127 (2016): 716-725.

LE Group Industries. LE Group Industries. 2016. https://legroupindustries.com/technical-specifications-for-rice/ (accessed 03 25, 2017).

Lemus, Christelle, Apostolis Angelis, Maria Halabalaki, and Alexios Leandros Skaltsounis. "Chapter 32 - Î³-Oryzanol: An Attractive Bioactive Component from Rice Bran ." In *Wheat and Rice in Disease Prevention and Health* , edited by Ronald Ross Watson, Victor R. Preedy and Sherma Zibadi, 409-430. San Diego: Academic Press, 2014.

Liang, Xiuying, Ke Wang, Chenglong Huang, Xuehai Zhang, Jianbing Yan, and Wanneng Yang. "A high-throughput maize kernel traits scorer based on line-scan imaging ." *Measurement* 90 (2016): 453-460.

Lin, P., Y.M. Chen, Y. He, and G.W. Hu. "A novel matching algorithm for splitting touching rice kernels based on contour curvature analysis ." *Computers and Electronics in Agriculture* 109 (2014): 124-133.

Liu, Fei, Wenwen Kong, and Yong He. "Quality determination of fruit vinegars using visible/near infrared spectroscopy and least squares-support vector machine." *African Journal of Agricultural Research* (Academic Journals) 7, no. 15 (2012): 2395-2404.

Lloyd, BJ, AG Cnossen, and TJ Siebenmorgen. "Evaluation of two methods for separating head rice from brokens for head rice yield determination." *Applied Engineering in Agriculture* (ASAE AMERICAN SOCIETY OF AGRICULTURAL) 17, no. 5 (2001): 643-648.

Lohumi, Santosh, Sangdae Lee, Hoonsoo Lee, and Byoung-Kwan Cho. "A review of vibrational spectroscopic techniques for the detection of food authenticity and adulteration ." *Trends in Food Science \& Technology* 46, no. 1 (2015): 85-98.

M. Ogata, K. Ukai, T. Kawai. "Visual fatigue in congenital nystagmus caused by viewing images of color sequential projectors." 1, no. 2 (2005): 314-320.

Mahajan, Sheetal, and Sukhvir Kaur. "Quality Analysis of Indian Basmati Rice Grains Using Digital Image Processing-A Review." (Citeseer).

Maheshwari, Chetan V. "Quality Assesment of ORYZA SATIVA SSP INDICA (Rice) using computer vision." *International Journal of Innovative Research in Computer and Communication Engineering* 1, no. 4 (2013).

Mandal, S, S Roy, and H Tanna. "A low-cost image analysis technique for seed size determination." *Current Science(Bangalore)* (Indian Academy of Sciences, C. V. Raman Avenue P. O. Box 8005 Sadashivanagar, Bangalore 560 080 India) 103, no. 12 (2012): 1401-1403.

Mollo, Giovanna, Theodoros Karapanagiotidis, Boris C. Bernhardt, Charlotte E. Murphy, Jonathan Smallwood, and Elizabeth Jefferies. “An individual differences analysis of the neurocognitive architecture of the semantic system at rest .” *Brain and Cognition* 109 (2016): 112-123.

Muhammad A. Shahin, Stephen J. Symons. “Color Calibration of Scanners for Scanner-Independent Grain Grading.” 80, no. 3 (2003): 285-289.

NinoLab-The Basic Principles of Sieve Analysis. 12 5 2014. http://www.ninolab.se/fileadmin/Ninolab/pdf/retsch/documents/af_sieving_basics_2004_en.pdf (accessed 5 12, 2014).

Ogata, Masaki, Kazuhiko Ukai, and Takashi Kawai. “Visual fatigue in congenital nystagmus caused by viewing images of color sequential projectors.” *Display Technology, Journal of* (IEEE) 1, no. 2 (2005): 314-320.

Pan, Ting, Lingxiao Zhao, Lingshang Lin, Juan Wang, Qiaoquan Liu, and Cunxu Wei. “Changes in kernel morphology and starch properties of high-amylose brown rice during the cooking process .” *Food Hydrocolloids* , 2016: - .

Patil, V, VS@article{mahajanquality, title={Quality Analysis of Indian Basmati Rice Grains Using Digital Image Processing-A Review}, author={Mahajan, Sheetal Malemath, and Sukhvir}, publisher={Citeseer} } Kaur. “Quality analysis and grading of rice grain images.” *Quality analysis and grading of rice grain images.* IJIRCCE, 2015.

Phophalia, Ashish, and Suman K. Mitra. “3D MR image denoising using rough set and kernel PCA method.” *Magnetic Resonance Imaging* 36 (2016): 135-145.

Porikli, F. “Inter-Camera Color Calibration by Correlation Model Function.” 3 (2004): 133-136.

Prajapati, Bhavesh B, and Sachin Patel. “Algorithmic approach to quality analysis of Indian basmati rice using digital image processing.” *International Journal of Emerging Technology and Advanced Engineering (ISSN 2250-2459, ISO 90001: 2008certified journal)* 3, no. 3 (2013): 503-504.

Raj, Mayur P, Priya R Swaminarayan, and Anand ISTAR. “Applications of Image Processing for Grading Agriculture products.” 2015.

Ramya, P, et al. “QTL mapping of 1000-kernel weight, kernel length, and kernel width in bread wheat (Triticum aestivum L.).” *Journal of applied genetics* (Springer) 51, no. 4 (2010): 421-429.

Rice Authority. Rice Authority. 8 10 2016. http://www.riceauthority.com/ (accessed 3 25, 2017).

"Rice Knowledge Bank - IRRI." 2016. http://www.knowledgebank.irri.org/index.php?option=com_zoo&task=item&item_id=1124&Itemid=822.

"Rice Quality Analyzer – Model RN 300 manual by Kett (Science of sensing)." *Rice Quality Analyzer – Model RN 300 manual by Kett (Science of sensing).*

Sabri Gurbuz, Masahiro Kawakita, Hiroshi Ando. "Color Calibration for Multi-camera Imaging Systems." 4 (2010): 201-206.

Sansomboonsuk, Siriluk, and Nitin Afzulpurkar. "The appropriate algorithms of image analysis for rice kernel quality evalution." *20th conference of mechanical engineering network of Thailand, Bangkok, Thailand.* 2006. 18-20.

SeedCount Australasia Pty Ltd. "Digital Image Analysis System for Grain." Weiss Enterprises: SeedCount Australasia Pty Ltd.

SeedCount-Ltd. "Digital Image Analysis System for Grain." Weiss Enterprises: SeedCount Australasia Pty Ltd, 2006.

Shih-Mim Liu, Yan-Chi Chou. "Color Calibration for a Surrounding True-Color LED Display System by PWM Controls." 61, no. 11 (2014): 6244-6252.

Shouche, SP, R Rastogi, SG Bhagwat, and Jayashree Krishna Sainis. "Shape analysis of grains of Indian wheat varieties." *Computers and electronics in agriculture* (Elsevier) 33, no. 1 (2001): 55-76.

"sra-010914.pdf." *http://dfpd.nic.in/.* Department of Food & Public Distribution. 1 9 2014. http://dfpd.nic.in/writereaddata/images/pdf/sra-010914.pdf (accessed 3 25, 2017).

Stark, Charles. "Factors that Influence Corn Particle Size and its Impact on Pellet Quality." *Factors that Influence Corn Particle Size and its Impact on Pellet Quality.* North Carolina (NC State). Feed Mill Education Unit. North Carolina State University, 2010.

Sun, Chengming, et al. "Evaluation and analysis the chalkiness of connected rice kernels based on image processing technology and support vector machine ." *Journal of Cereal Science* 60, no. 2 (2014): 426-432.

Tecnico Lisboa - Particle size. https://fenix.tecnico.ulisboa.pt. 1998. https://fenix.tecnico.ulisboa.pt/downloadFile/3779573890036/D422-particle%20size.pdf (accessed 8 4, 2017).

"The Basic Principles of Sieve Analysis - Ninolab." *www.ninolab.se.* RETCH. 2004. www.ninolab.se/fileadmin/Ninolab/pdf/retsch/.../af_sieving_basics_2004_en.pdf (accessed 4 23, 2017).

UCMerced University. 2014. https://eng.ucmerced.edu/snsjho/files/MHWG/Laboratory/Soils/Protocol/Chapter_9_Grain_size_analysis.pdf (accessed 4 8, 2017).

"US Grains." 2016. http://www.grains.org/buyingselling/importer-manual/chapter-4-grain-quality-and-us-standards.

"US Grains Council." 1988. http://www.grains.org/buyingselling/importer-manual/chapter-4-grain-quality-and-us-standards.

Vaighai Worldwide. Vaighai Worldwide. 2016. http://www.vaighaiworldwide.com/rice-products.html (accessed 3 25, 2017).

Valency International Trading Pte Ltd. Valency International Trading Pte Ltd. 2016. http://www.valencyinternational.com/maize-corn-specifications.php (accessed 03 25, 2017).

Verma, Bhupinder. "Image processing techniques for grading \& classification of rice." *Computer and Communication Technology (ICCCT), 2010 International Conference on.* 2010. 220-223.

Villez, Kris, Venkat Venkatasubramanian, and Raghunathan Rengaswamy. "Generalized shape constrained spline fitting for qualitative analysis of trends ." *Computers \& Chemical Engineering* 58 (2013): 116-134.

Voicu, Gheorghe, Gabriel-Alexandru Constantin, Elena-Madalina Stefan, and Paula Voicu. "Particle size distribution of wheat grist fractions in plansifter compartments of a five breaks roller mill system." *Journal of Engineering Studies and Research* (Universitatea" Vasile Alecsandri" din Bacau) 19, no. 2 (2013): 102.

Wan, YN, and Mei Fangquan. "Automatic grain quality inspection with learning mechanism." *AFITA 2002: Asian agricultural information technology \& management. Proceedings of the Third Asian Conference for Information Technology in Agriculture, Beijing, China, 26-28 October, 2002.* 2002. 445-449.

Wang, N, N Zhang, FE Dowell, and T Pearson. "Determining vitreousness of durum wheat using transmitted and reflected images." *Transactions of the ASAE* (American Society of Agricultural and Biological Engineers) 48, no. 1 (2005): 219-222.

Wang, Ning, FE Dowell, and Naiqian Zhang. "Determining wheat vitreousness using image processing and a neural network." *Transactions of the ASAE* (American Society of Agricultural and Biological Engineers) 46, no. 4 (2003): 1143.

Welna, Maja, Anna Szymczycha-Madeja, and Pawel Pohl. "Comparison of strategies for sample preparation prior to spectrometric measurements for determination and speciation of arsenic in rice." *TrAC Trends in Analytical Chemistry* 65 (2015): 122-136.

Wenfang, Huang Li1 Bai Yun2 Han, Yu Xiaoying1 Zhu Feifei1 Xiong Shanbai, and Zhao Siming. “Effect of Rice Quality on the Food Safety [J].” *Journal of the Chinese Cereals and Oils Association* 4 (2013): 022.

Wikipedia. wikipedia. 14 3 2017. https://en.wikipedia.org/wiki/Basmati#cite_note-bloomberg-6 (accessed 3 25, 2017).

Xu, Xia, Fan Chao, Lu Shu-Jie, and Hou Li-Long. “The analysis of wheat appearance quality based on digital image processing.” *Environmental Science and Information Application Technology (ESIAT), 2010 International Conference on.* 2010. 231-234.

Yadav, BK, and VK Jindal. “Monitoring milling quality of rice by image analysis.” *Computers and Electronics in Agriculture* (Elsevier) 33, no. 1 (2001): 19-33.

Yang S, Hu Y, Huang H Zhao S Li X. “Near infrared rapid detection of protein, fat, starch and water in rice.” no. 3 (2015): 52-56.

Yao, Qing, Ding xiang Xian, Qing jie Liu, Bao jun Yang, Guang qiang Diao, and Jian Tang. “Automated Counting of Rice Planthoppers in Paddy Fields Based on Image Processing.” *Journal of Integrative Agriculture* 13, no. 8 (2014): 1736-1745.

Yao, Qing, Jianhua Chen, Zexin Guan, Chengxiao Sun, and Zhiwei Zhu. “Inspection of rice appearance quality using machine vision.” *Intelligent Systems, 2009. GCIS'09. WRI Global Congress on.* 2009. 274-279.

Yoshioka, Yosuke, Hiroyoshi Iwata, Minako Tabata, Seishi Ninomiya, and Ryo Ohsawa. “Chalkiness in rice: potential for evaluation with image analysis.” *Crop Science* (Crop Science Society of America) 47, no. 5 (2007): 2113-2120.

Yu, L., M.S. Turner, M. Fitzgerald, J.R. Stokes, and T. Witt. “Review of the effects of different processing technologies on cooked and convenience rice quality.” *Trends in Food Science \& Technology* 59 (2016): 124-138.

Zhao, Miaomiao, Hongxia Liu, and Yi Wan. “An improved Canny edge detection algorithm based on DCT.” *Progress in Informatics and Computing (PIC), 2015 IEEE International Conference on.* 2015. 234-237.