International Journal of Computer and Organization Trends
ISSN: 2249 – 2593 / https://doi.org/10.14445/22492593/IJCOT-V13I1P304
Volume 13 Issue 1, 16-22, Jan-Apr 2023

Original Article

Deep Learning for Analysing Rice Quality

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Received: 01 March 2022 Revised: 05 April 2023 Accepted: 20 April 2023 Published: 30 April 2023

Abstract *- The demand for high-quality rice is a top priority in the rice manufacturing industry, as rice is the most consumed food worldwide. The physical dimensions of rice, including length, width, and thickness, are important factors in assessing rice quality. However, traditional methods of measuring these factors are time-consuming and imprecise due to manual evaluation. To meet market demands, rice quality evaluation is critical in the rice production industry, with factors such as whiteness, shape, milling degree, chalkiness, cracks, and polish being key indicators of rice quality. Ensuring rice quality is crucial to protect consumers from substandard products, particularly given that more than half the world's population relies on rice as a primary dietary staple. While rice is a rich source of energy, protein, essential vitamins and minerals, fibre, grain, beneficial antioxidants, and carbohydrates, manual evaluation of rice kernels for quality analysis is complex, time-consuming, and prone to human bias. To address these challenges and achieve high-quality rice, image processing techniques have a significant role to play. This project reviews various techniques for assessing rice quality using image processing, which is essential for seed identification and classification, grading, and quality determination in seed science and food processing sectors.*

Keywords *- Milling degree, Chalkiness, Whiteness, Grain, Antioxidants, and Carbohydrates.*

1. Introduction

The quality of rice has a significant impact on both consumer preferences and the price of rice. The physical and chemical characteristics of rice determine its quality and, in turn, affect its price. Therefore, establishing rice quality standards and criteria is essential for determining rice prices. The criteria used to determine the price of rice include the level of dryness (moisture content), cleanliness (percentage of foreign materials), the appearance of intact rice (percentage of head rice, broken rice, minutes kernel, green and chalkiness grain), the condition of undamaged rice (percentage of yellow/damaged grain), the color of white rice (polished degree, the percentage of red grains), and the absence of paddy grain. Rice quality can be affected by various factors, such as the variety of rice, agroecosystems, cultivation techniques, post-harvest handling and processing, equipment, human resources, and social culture. It is essential to ensure that these factors are carefully managed to maintain high-quality rice and prevent any manipulation of rice quality.

Quality analysis methods for paddy grain and rice are necessary to determine their quality in Madagascar. These methods can be used to develop laboratory analyses for paddy grain and rice quality and to design the Madagascar National Standard Format (SNM) for paddy grain and rice in the future.

Machine vision plays a crucial role in assessing the quality of rice. While some researchers propose that an object's shape holds more information than its appearance properties, such as color variation, it is not entirely reliable for producing accurate results. However, it can help detect issues with rice integrity, such as seed touching during sample collection. The

The primary objective of this approach is to provide an alternative means of quality control and rice analysis that reduces the associated effort, cost, and time requirements.

1.1. Grain Quality

The quality of grain in agriculture is determined by its intended use. For ethanol production, the chemical makeup of grain, particularly its starch content, is critical. In food and feed manufacturing, the properties of protein, oil, and sugar are significant. Soundness is the most crucial factor in determining grain quality in the milling industry. For grain farmers, high germination percentage and seed dormancy are the primary considerations. For consumers, factors such as color and flavor are of utmost importance. The overall quality of grain is influenced by several factors, including growing practices, timing and method of harvesting, post-harvest handling, storage management and transportation practices. The key properties of grain quality can be summarized into ten factors: (i) uniform moisture content, (ii) high test weight, (iii) no impurities, (iv) a low percentage of kernels discolored, broken and damaged, (v) low breakage, (vi) high milling quality, (vii) high protein and oil content, (viii) high viability, (ix) absence of aflatoxin (mycotoxin), and (x) absence of insects and molds. Grain quality can be classified into two main types of factors: intrinsic and extrinsic. Intrinsic factors refer to properties inherent to the grain, such as color, composition, bulk density, odour, aroma, size, and shape. Color is a crucial primary factor in the grading, processing, trade, and characterization of grain. This is commonly used to criterion the wheat trade. The primary constituents of grain are carbohydrates, protein, lipids, minerals, fiber, physic, and tannins, and their composition can vary significantly depending on the type of grain, genetics, variety, agricultural practices, and handling of the grain. Grain composition plays a vital role in the grading and marketing of grains. Bulk density is a measure of the ratio of the mass to a given volume of a grain sample, including the interstitial voids between the particles. It is an important factor to consider when assessing grain quality. Grain grading and specification systems play a crucial role in ensuring that a given lot of grain conforms to the required standards set by food regulation authorities, such as the FDA in the United States and the FSA in the United Kingdom. In numerous countries, the grading of grain is based on four primary properties: (i) bushel (test) weight, (ii) moisture content, (iii) the percentage of broken foreign material or fragments, such as broken corn foreign materials, and (iv) damaged kernels, including total and heat damage.

1.2. Test Weight

The test weight, also referred to as volumetric weight, is a simple and conventional criterion utilized to assess the quality of grain and measure grain bulk density. It serves as an indicator of overall grain quality and primary grain specification. Typically, higher test weights signify higher quality, whereas lower test weights suggest lower quality, and grain quality decreases significantly as the grain deteriorates. Numerous factors affect the test weight of grain, including initial and final moisture contents, frost damage, maturity, growing and harvesting conditions, drying conditions, fine material, degree of kernel damage, and variety.

1.3. Moisture Content

Moisture content is a critical factor in evaluating grain quality. It is quantified as the amount of water per unit mass of grain and is typically expressed as a percentage on a wet basis or dry basis. While moisture content does not have a direct impact on grain quality, it can have an indirect effect since grain will deteriorate if the moisture content exceeds the recommended level for storage.

1.4. Foreign Material (FM)

Broken foreign material is a crucial factor in grading and classifying grains. It refers to any foreign material in a particular lot of grain that is not part of the grains themselves, such as sand, pieces of rock, microplastics, metals, and glass fragments. In the grain trade, the presence of an excessive amount of foreign material above a predetermined percentage results in low grades, price discounts, or lot rejection, as the higher the amount of foreign material, the more expensive it becomes to clean the grain before use.

1.5. Damaged Kernel (DK)

The presence of damaged kernels is a crucial factor in determining the quality of the grain, and it can have a negative impact on its value. Kernels that show visible damage are classified as DK. The quantification of DK is typically done by manually removing them from clean portions of the grain. Each grade of grain has specific criteria for the allowable amount of DK, with a maximum limit set for each grade. For example, in order for wheat to be classified as Grade 1, DK must not exceed 0.4% of the total weight. Damage to kernels can be caused by various factors, including insects, heat, mould, weathering, sprouting, frost, diseases, uneven maturity, and incomplete grain filling. In grading and specification systems, damaged kernels are generally divided into two categories: heat damaged and totally damaged.

1.6. Non-Grain-Standard Properties

Grain standards comprise crucial non-grain criteria, such as breakage susceptibility, milling quality, seed viability, nutritive value, mould count, carcinogen content, and insect infestation and damage. Wheat and rice are two frequently cited grains that exemplify superior grain quality.

3. Review of Literature

3.1. PrabirakumarSethy [10]

The rice production industry places great importance on evaluating rice quality in response to market demand. Factors such as whiteness, shape, milling degree, chalkiness, cracks, and polish are all evaluated to ensure rice's quality and protect consumers from substandard products. Rice is a primary dietary staple for more than half of the world's population, providing energy, protein, essential vitamins and minerals, fiber, grain, beneficial antioxidants, and carbohydrates. However, manual analysis of rice kernel for quality evaluation is complicated, time-consuming, and subject to human perception bias, leading to errors. To overcome these issues and achieve consistent rice quality, image processing techniques have a wide range of applications. This paper reviews different techniques used to evaluate rice quality using image processing methods. The essential roles of these techniques include identifying and classifying seeds, grading seeds, and quality determination of seeds in both seed science and food processing sectors.

3.2. Dr.T.Avudaiappan, S.Sangamithra, A.Silpharoselin, S.Sherinfarhana, KM.Visalakshi [6]

Rice serves as the primary source of sustenance in Southern India and is also the staple food for over 80% of the world's population. Various types of paddy crops are grown and form exported globally. Detecting defective grains and identifying rice variety are crucial aspects of rice quality analysis. An automated system has been introduced for identifying and classifying rice grain types of quality, where digital imaging is employed as an efficient technique for extracting features from rice grains in a non-contact manner. Images are captured using a camera, followed by image pre-processing techniques such as filtering, segmentation, and edge detection. The extracted morphological features from the image are fed into a machine-learning algorithm, and the output is displayed on an LED.

3.3. Herath H.M.K.K.M.B and Eng. de Mel W.R [7]

Rice is a major staple crop consumed by humans all over the world, especially in Asian countries. It is typically categorized based on characteristics such as grain shape and colour. This study examines using a machine vision system for rice grain classification. Machine vision has been widely used in grain classification applications to distinguish rice varieties based on special features such as shape, length, chalkiness, colour, and internal damage. Various techniques, including the RGB color texture model, histogram, and edge, have been used to differentiate and analyze rice grains. This paper proposes methods for classifying four rice varieties and determining the percentage of pure rice grains using image processing techniques based on several features, such as grain colour and shape.

3.4. Mohan, D., & Raj, M. G. [9]

Rice is a widely consumed food worldwide, and its market value depends on its quality. The current method for assessing rice type and quality involves visual inspection by a human, which is tedious, time-consuming, requires expertise, and can be affected by the physical state of the inspector. To address these limitations, this paper proposes an automated system that utilizes digital image processing techniques to identify and classify rice grains. This approach is preferred as it is non-contact and involves capturing images of rice grains. The captured images are pre-processed, segmented, and features are extracted using MATLAB. The quality of rice is assessed based on the extracted features using Neural Networks (NN) and Support Vector Machine (SVM) classifier algorithms. A comparative study between these two methods is conducted, and the results demonstrate that SVM-based classification outperforms its counterpart. This study is titled "Computer vision and machine learning analysis of commercial rice grains: A potential digital approach for consumer perception studies" and was published in Sensors, 21(19), 6354. Aznan, A., Gonzalez Viejo, C., Pang, A., & Fuentes [4] Assessing the quality of commercial rice grain is crucial for meeting consumer demands and high-quality standards. However, developing cost-effective and efficient techniques for rice quality assessment remains challenging. This paper proposes a digital approach using computer vision (CV) and machine learning (ML) to classify commercial rice samples based on morphometric and colorimetric parameters extracted from digital images captured by a smartphone camera. The proposed approach uses an artificial neural network (ANN) model to classify rice samples into 15 commercial rice types based on nine morph-colorimetric parameters. The ANN model is evaluated using the Bayesian Regularization (BR) algorithm with ten hidden neurons. The results show that the model achieves 91.6% (MSE = <0.01) and 88.5% (MSE = 0.01) classification accuracy for the training and testing stages, respectively, with an overall accuracy of 90.7% (Model 2). Furthermore, the ANN models are evaluated on a different imaging system, and the results show high accuracy (93.9%) in classifying the rice samples. The proposed approach offers a rapid, reliable, and accurate method for rice quality assessment that can be incorporated into consumer perception studies.

3.5. Aznan, A., Gonzalez Viejo, C., Pang, A., & Fuentes [3]

The assessment of rice quality traits such as aroma and physicochemical parameters is crucial in determining consumer perception and acceptance of rice. However, current methods that employ multiple instruments and laboratory analysis are both time-consuming and costly. This study aimed to evaluate the quality of 17 commercial rice types by utilizing a low-cost electronic nose and portable near-infrared spectrometer coupled with machine learning (ML). Specifically, artificial neural networks (ANN) were utilized to classify rice types and predict rice quality traits such as aroma, color, texture, and pH of cooked rice as targets. The ML models developed were successful in classifying rice types (Model 1: 98.7%; Model 2: 98.6%) and predicting the peak area of aromas detected by gas chromatography-mass spectroscopy in both raw (Model 3: R = 0.95; Model 6: R = 0.95) and cooked rice (Model 4: R = 0.98; Model 7: R = 0.96).

Furthermore, a high R = 0.98 was achieved for Model 5 to estimate the colors, texture, and pH of cooked rice. This method is rapid, low-cost, and reliable. It could be instrumental in helping the rice industry improve the quality of rice production and expedite the adoption of digital technologies and artificial intelligence to support the rice value chain.

3.6. Izquierdo, M., Lastra-Mejías, M., González-Flores, E., Pradana-López S., Cancilla, J. C., &Torrecilla, J. S. [8]

This study utilized over 27,000 images of five different varieties of Oryza sativa L. to develop and validate a deep learning-based system for their classification. The images were captured using a typical photographic camera and were processed using convolutional neural networks (CNNs) that were trained and optimized to identify different types of rice. The resulting algorithm was able to detect and classify all five types of rice accurately, and it was validated using images that were not included in the training database. The use of CNNs has demonstrated their effectiveness as a tool for evaluating rice, including for quality purposes, due to their high sensitivity, speed, and ease of implementation without requiring highly specialized personnel.

3.7. Chen, S., Xiong, J., Guo, W., Bu, R., Zhen, Z., Chen, Y.& Lin [5]

Evaluating rice quality using machine vision is crucial for achieving automated rice production and processing. This study focused on red indicia rice and developed a machine vision system that identifies flawed rice kernels, including broken, chalky, damaged, or spotted ones. The system collected near-infrared images of rice samples and applied a support vector machine (SVM) classifier to identify broken rice kernels using the invariant moment ellipse major axis as input. The system obtained head rice images and applied another SVM to perform gray-level segmentation. The chalky areas were accurately extracted by doubly examining the segmented areas using the centred distance constraint and the pixel search positioning method. Finally, the system detected the damaged and spotted areas on rice kernels using edge detection and morphological methods. The experimental results showed that the recognition accuracy for broken kernels, chalkiness, and damaged and spotted areas were 99.3%, 96.3%, and 93.6%, respectively. The proposed method took an average of 0.15 s to detect all four types of defects. Therefore, the method has significant potential to be used for rapid and accurate quality detection of colored rice and to provide technical support for machine vision-based inspection and automated grading of rice.

3.8. Analysing Rice Seed Quality [1]

Quality assessment of rice grains presents a great challenge in the food industry. Testing for quality has gained importance in classifying and grading rice grains. However, manual testing is time-consuming, expensive, and prone to inaccuracies. Yes, grain quality analysis based on machine vision is preferred. Machine vision-based testing involves the evaluation and grading of rice grains based on both physical (grain shape and size colour) and chemical characteristics (amylose content, gel consistency). Quality assessment is performed by measuring the length, breadth, and diagonal size of each grain to determine the region of the boundary and the endpoints of the grain. In this proposed image processing algorithm, the quality and grading of rice grains were analyzed using the average values of the extracted features, and the algorithm was implemented in Matlab.

3.9. Ahmed, S. B., Ali, S. F., & Khan, A. Z. [2]

Rice is a valuable subsistence crop that feeds over 3.5 billion people worldwide. Its significance is evident from the fact that the top five rice-exporting countries had a combined net export value of approximately $19 billion in 2018. A reliable system for analyzing and classifying rice grains can significantly enhance performance in terms of accuracy and time. Due to its socioeconomic impact, this research area has gained substantial attention in recent decades. This paper provides a review of image-based rice classification and grading work. The study has a three-fold contribution: first, it categorizes the algorithms and techniques into five different approaches - geometric, statistical, supervised, unsupervised, and deep learning, where deep learning techniques have exhibited more promising results and are attracting attention for future research. Second, it divides the literature on rice grain into three different historical eras. Third, it summarizes various algorithms and techniques concerning rice quality grading and disease identification.

4. Proposed Methodology

The proposed method aims to offer a cost-effective and time-saving alternative for quality analysis. Image processing is a crucial and rapidly advancing field which has seen significant advancements. There is a concerted effort to replace traditional human sensory panels. The system architecture outlines the procedure for accurate diagnosis of rice quality. The primary steps involved are image processing and image classification. Image processing can easily perform segmentation and feature extraction, resulting in high accuracy and performance.

4.1. Dataset Collection and Pre-processing

The term "dataset" refers to a set of data typically presented in tabular form, with each column representing a specific variable and each row corresponding to a particular dataset member. For instance, the values in the table may indicate the height and weight of an object. Each value is called a datum. We have opted to use a Healthcare dataset that is publicly available, featuring a relatively small number of inputs and cases. The dataset is organized in such a way that professionals in the medical field can easily relate familiar statistical methods with new ML techniques. The sklearn pre-processing package offers numerous standard utility functions and transformer classes to convert raw feature vectors into a more appropriate format for downstream estimators.

4.2. Standardization, or Mean removal and Variance Scaling

It is a common prerequisite for many machine learning estimators in scikit-learn to standardize datasets, as they may perform poorly if the individual features are not distributed in a manner similar to standard normal data, i.e., Gaussian with a mean of zero and a variance of one.

4.3. Scaling Features to a Range

It is a common prerequisite for many machine learning estimators in scikit-learn to standardize datasets, as they may perform poorly if the individual features are not distributed in a manner similar to standard normal data, i.e., Gaussian with a mean of zero and a variance of one.

4.4. Normalization

The process of normalization involves scaling individual samples to have a unit norm. This can be advantageous when using a quadratic form like the dot-product or kernel to assess the similarity between any two samples. This assumption is the foundation of the Vector Space Model, which is frequently utilized in text classification and clustering scenarios.

4.4. Segmentation

The process of dividing and grouping similar data based on chosen parameters is known as data segmentation. This process enables more efficient use of data for marketing and operational purposes. Four common segmentation types include demographic, psychographic, geographic, and behavioural.

4.5. Feature Extraction

Feature extraction is an essential process in machine learning, pattern recognition, and image processing. It involves deriving informative and non-redundant features from measured data to facilitate subsequent learning and generalization. The data can be transformed into a reduced set of features, also known as a feature vector. The process of selecting a subset of initial features is called feature selection, with the aim of retaining only relevant information that can be used for the desired task using the reduced representation.

4.6. Analysis Quality

Data quality refers to the state of your data, measured by factors like accuracy, consistency across data sources, integrity, and usability. High-quality data scores well across all of these factors and is the ideal data type for processing and analysis. The process of analyzing data quality is the final step of the data understanding stage, during which potential errors, shortcomings, and issues in the datasets are identified.

4.7. System Architecture

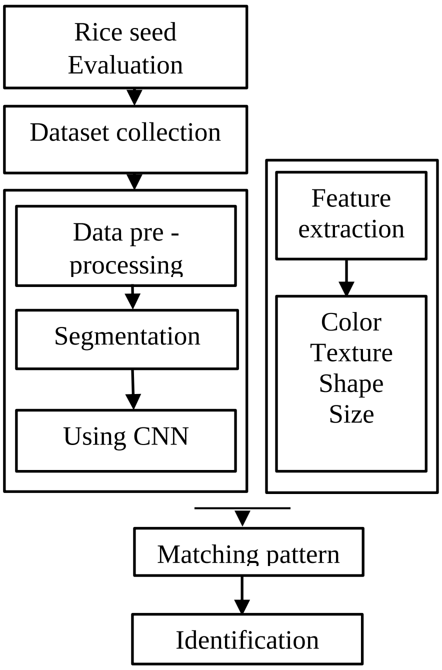

Fig. 1 Data collection architecture

5. Experimental Results

{'bad': 0, 'good': 1 }

{ 0: 'bad', 1: 'good'}

A cost matrix is provided with the dataset that gives a different penalty to each misclassification error for the positive class. Specifically, a cost of five is applied to a false negative (marking a bad as good), and a cost of one is assigned to a false positive (marking a good as bad).

Epoch 1/5

30/30{==============================} - 146s 5s/step - loss: 0.0000e+00 - accurcy: 0.9808

Epoch 2/5

30/30{==============================} - 140s 5s/step - loss: 0.0000e+00 - accurcy: 0.9793

Epoch 3/5

30/30{==============================} - 140s 5s/step - loss: 0.0000e+00 - accurcy: 0.9830

Epoch 4/5

30/30{==============================} - 140s 5s/step - loss: 0.0000e+00 - accurcy: 0.9847

Epoch 5/5

30/30{==============================} - 124s 4s/step - loss: 0.0000e+00 - accurcy: 0.9809

An epoch refers to one cycle through the full training dataset. Usually, training a neural network takes more than a few epochs—loss: A scalar value that we attempt to minimize during our training of the model.

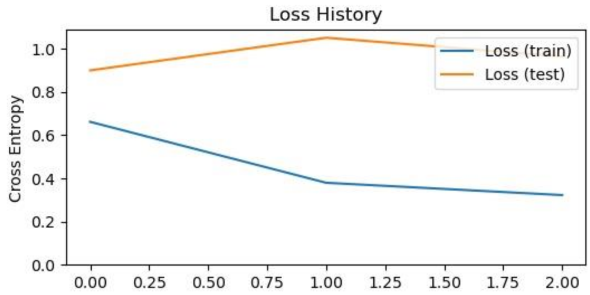

Fig. 2 Image labelling.

Cross-entropy is commonly used in machine learning as a loss function. Cross-entropy is a measure from the field of information theory, building upon entropy and generally calculating the difference between two probability distributions. It is closely related to but is different from KL divergence, which calculates the relative entropy between two probability distributions, whereas cross-entropy can be thought to calculate the total entropy between the distributions. Cross-entropy is also related to and often confused with logistic loss, called log loss.

6. Conclusion and Future Work

The purpose of this project was to conduct a survey on the utilization of image processing techniques in automated rice grading systems within an agricultural context. The majority of previous work in this area has employed methods such as background subtraction, feature extraction, and training and classification. The literature also includes an exploration of image processing-based approaches for automatic rice recognition, classification, and identification of foreign particles using color and texture features. The selection of the most suitable techniques is essential to support decision-making.

References

[1] Sheikh Bilal Ahmed, Syed Farooq Ali, and Aadil Zia Khan, "On the Frontiers of Rice Grain Analysis, Classification and Quality Grading: A Review," *IEEE Access*, vol. 9, pp. 160779-160796, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[2] Aimi Aznan et al., "Computer Vision and Machine Learning Analysis of Commercial Rice Grains: A Potential Digital Approach for Consumer Perception Studies," *Sensors*, vol. 21, no. 19, p. 6354, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[3] Aimi Aznan et al., "Rapid Assessment of Rice Quality Traits Using Low-Cost Digital Technologies," *Foods,* vol. 11, no. 9, p. 1181, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[4] Shumian Chen et al., "Colored Rice Quality Inspection System Using Machine Vision," *Journal Of Cereal Science,* vol. 88, pp. 87-95, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[5] T. Gayathri Devi, P. Neelamegam, and S. Sudha, "Machine Vision Based Quality Analysis of Rice Grains," *2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering*, pp. 1052-1055, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[6] Dr. T. Avudaiappan et al., "Analysing Rice Seed Quality Using Machine Learning Algorithms," *SSRG International Journal of Computer Science and Engineering*, pp. 22-26, 2020. [Google Scholar] [Publisher Link]

[7] Herath H.M.K.K.M.B, and Eng. de Mel W.R, "Rice Grains Classification Using Image Processing Technics," 2020. [Google Scholar] [Publisher Link]

[8] Manuel Izquierdo et al., "Visible Imaging to Convolutionally Discern and Authenticate Varieties of Rice and Their Derived Flours," *Food Control*, vol. 110, p. 106971, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[9] Divya Mohan, and Murugananth Gopal Raj, "Quality Analysis of Rice Grains Using ANN and SVM," *Journal of Critical Reviews,* vol. 7, no. 1, pp. 395-402, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[10] Prabira Kumar Sethy, "Rice Quality Evaluation Based on Image Processing," 2020.

[11] Biren Arora et al., "Rice Grain Classification using Image Processing & Machine Learning Techniques," *2020 International Conference on Inventive Computation Technologies*, pp. 205-208, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[12] Rahul Nijhawan et al., "A Hybrid Deep Learning Framework Approach for the Detection of Different Varieties of Grain Types," *2021 10th International Conference on System Modeling & Advancement in Research Trends*, pp. 307-311, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[13] Sheikh Bilal Ahmed, Syed Farooq Ali, and Aadil Zia Khan, "On the Frontiers of Rice Grain Analysis, Classification and Quality Grading: A Review," *IEEE Access*, vol. 9, pp. 160779-160796, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[14] Israa Hassan Bashier, Mayada Mosa, and Sharief Fadul Babikir, "Sesame Seed Disease Detection Using Image Classification," *2020 International Conference on Computer, Control, Electrical, and Electronics Engineering*, pp. 1-5, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[15] Chen Xiao et al., "Grain Classification Using Hierarchical Clustering and Self-Adaptive Neural Network," *2008 7th World Congress on Intelligent Control and Automation*, pp. 4415-4418, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[16] Ouiza Adjemout, Kamal Hammouche, and Moussa Diaf, "Automatic Seeds Recognition by Size, Form and Texture Features," *2007 9th International Symposium on Signal Processing and Its Applications*, pp. 1-4, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[17] Si Chen et al., "Classification Model of Seed Cotton Grade Based on Least Square Support Vector Machine Regression Method," *2012 IEEE 6th International Conference on Information and Automation for Sustainability*, pp. 198-202, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[18] Kantip Kiratiratanapruk, and Wasin Sinthupinyo, "Color and Texture for Corn Seed Classification by Machine Vision," *2011 International Symposium on Intelligent Signal Processing and Communications Systems*, pp. 1-5, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[19] Samson Damilola Fabiyi et al., "Varietal Classification of Rice Seeds Using RGB and Hyperspectral Images," *IEEE Access,* vol. 8, pp. 22493-22505, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[20] Ronnie Concepcion II et al., "Variety Classification of Lactuca Sativa Seeds Using SingleKernel RGB Images and Spectro-Textural-Morphological Feature-Based Machine Learning," *2020 IEEE 12th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management*, pp. 1-6, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[21] Lu Gao, Chunyu Zhao, and Manhua Liu, "Segmentation of Touching Seeds Based on Shape Feature and Multiple Concave Point Detection," *2017 IEEE International Conference on Imaging Systems and Techniques*, pp. 1-5, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[22] Bhagyashree Mahale, and Sapana Korde, "Rice Quality Analysis Using Image Processing Techniques," *International Conference for Convergence for Technology*, pp. 1-5, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[23] Maged Wafy, Hashem Ibrahim, and Enas Kamel, "Identification of Weed Seeds Species in Mixed Sample with Wheat Grains Using SIFT Algorithm," *2013 9th International Computer Engineering Conference*, pp. 11-14, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[24] James M. Keller, Michael R. Gray, and James A. Givens, "A Fuzzy K-Nearest Neighbor Algorithm," *IEEE Transactions on Systems, Man, and Cybernetics*, vol. SMC-15, no. 4, pp. 580-585, 1985. [CrossRef] [Google Scholar] [Publisher Link]

[25] K. Archana, and Dr.K.G.Saranya, "Crop Yield Prediction, Forecasting and Fertilizer Recommendation using Voting Based Ensemble Classifier," *SSRG International Journal of Computer Science and Engineering*, vol. 7, no. 5, pp. 1-4, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[26] Kuo-Yi Huang, and Mao-Chien Chien, "A Novel Method of Identifying Paddy Seed Varieties," *Sensors*, vol. 17, no. 4, p. 809, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[27] Samson Damilola Fabiyi et al., "Comparative Study of PCA and LDA for Rice Seeds Quality Inspection," *2019 IEEE Africon*, pp. 1-4, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[28] Mumenunnessa Keya, Bhaskar Majumdar, and Md. Sanzidul Islam, "A Robust Deep Learning Segmentation and Identification Approach of Different Bangladeshi Plant Seeds Using CNN," *2020 11th International Conference on Computing, Communication and Networking Technologies*, pp. 1-6, 2020. [CrossRef] [Google Scholar] [Publisher Link]