Classification in Cashew Grading System: A Systematic Review

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ABSTRACT
Quality is the most important aspect in cashew nuts, based on which the price is fixed. This makes classification an even more important process. The purpose of this study is to conduct a systematic literature review to identify existing knowledge in the cashew grading system. The search method discusses the papers based on feature extraction techniques, outcomes, and limitations. Also highlight the research gap or focus on the classification and recognition of defective cashews and computation time.

General Terms
Image Processing, Machine Learning

Keywords
Cashew Grading, Image Processing, Feature extraction, Machine learning, Deep learning

1. INTRODUCTION
Cashews have their origins in Brazil. The Portuguese brought it to Goa, and then India started to grow and export it to many foreign countries. It has a high nutritional value [13]. There is a huge demand for cashew in international as well as domestic markets. Now, India has many competitors in the international markets. Due to increasing demand, there is a need for an automated cashew grading system, but many countries still do it manually. Quality is one of the most important parameters for cashew, and there are a lot of challenges in the grading system for cashew. The present quality detection and grading systems have a few drawbacks, like low efficiency and high cost. Along with that, processing speed is also a challenge [19].

The processing of cashews involves the following steps: Raw cashew nut drying, roasting, steaming, shell removal, drying and cooling of shelled kernels, peeling, grading, filling, and packing [9, 10]. As shown in Table 1, there are different grades of whole cashews and broken cashews. Grading of cashew kernels is based on the size, shape, and colour of cashews. The grade is indicated by two or more alphabets and a number. W represents the White Whole Grade, which means the cashew kernels are white and free from damage; SW represents Scorched Whole, which means cashew kernels are light brown and free from damage; and DW is Desert Whole, which means cashew kernels are dark brown. It may show a deep black spot and is free from damage [5]. S represents Splits, B represents Butts, SS is Scorched Splits, SB is Scorched Butts, LWP is Large White Pieces, SWP is Small White Pieces, BB is Baby Bits, SP is Scorched Pieces, SSP is Scorched Small Pieces, SPS is Scorched Pieces Seconds, and DP is Dessert Pieces. Because of this requirement, identifying, segregating, and grading cashew kernels are prominent and frequently performed tasks.

Quality of cashews is of high importance and because of this requirement identifying, segregating and grading of cashew kernels are prominent tasks that are often performed in a manual process. Automating this process using Computer vision, Image Processing, Machine learning and Artificial Neural Networks seem to provide promising solutions to the effective and efficient grading system for cashews. It is observed that these mentioned techniques have already been successfully implemented for various other domains like agriculture. In this paper, a systematic literature review on the cashew grading system and the techniques used. The organization of this paper is as follows: Section 2 presents Review and Methods; Section 3 presents the Results and Discussion and Section 4 presents the Conclusion.

Table 1. Cashew Grades

Wholes	**Scorched Wholes**
WHOLE	SW
W180	SW180
W210	SW210
W240	SW240
W320	SW320
W450	SW450
W500	SW500
Broken White Pieces	**Scorched Pieces**
B	SB
S	SS
LWP	SP
SWP	SSP
BB	SPS
	DP

2. REVIEW AND METHODS
This literature survey was carried out to first understand the state of art of the cashew grading system and later to explore the mechanisms and techniques used in the assistance to grading system. Figure1 shows the literature review procedure. There are four steps: exploration, screening, segregation, and selection. The research papers were searched from databases like Web of Science, Scopus and Google Scholar with the keywords: “Cashew grading system”, “Image processing” , “Machine learning” and “ Machine vision” combined with “Cashew detection” , “Indian Cashew industry” , “ Cashew crop”, “Classification” , and “Deep neural network”

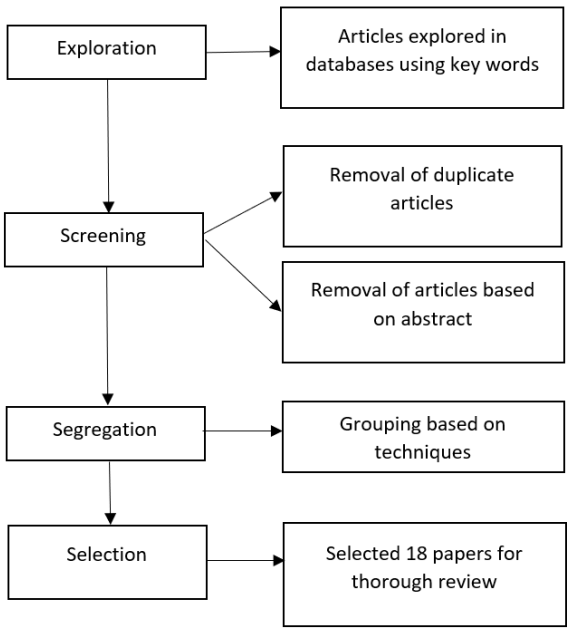

Figure 1. Literature Review Process

From the research articles found, the duplicates were removed. Also, abstracts were screened and those relevant to the research topic were retained. All the articles were grouped based on the techniques used. A wide variety of techniques are employed for cashew grading, like different machine learning algorithms, image processing, and deep learning algorithms. So, in the segregation step, the papers were grouped based on techniques. From these, eighteen papers were selected for thorough review. The analysis of the papers is presented and discussed in the next section.

3. RESULTS AND DISCUSSION

The literature search procedure resulted in the identification of relevant articles on the mentioned topic. In this section, the results of the literature review are detailed. Quality is an important aspect of cashews, and if there are defects in cashew kernels, they would be rejected for export. So, to maintain and check the quality, a grading system for cashews is used. Most of the time, it is done manually, which is time-consuming [1, 15]. Along with automation of grading, supply

chain management can also be optimized [11]. The cashew grading system deals with hardware like cameras and their resolutions, pixel values, conveyor belt speed and its dimensions, and shelling machines [2], accessories for the system. When translating from manual to automation, which is actually required in the current grading system, it deals with image capturing techniques, acquisition, and processing of images. Based on the images, the cashews are classified as good or bad quality.

The classification of cashews is done in four steps. First, the image of the cashews has to be captured. Second, the image requires some level of pre-processing. This makes the captured image appropriate by removing the noise or distortions, thereby improving the image quality so that various algorithms can be applied. Third, the dimension of the captured data has to be reduced, and this is done by feature extraction. Here, the features and properties are extracted. Lastly, rules are defined and the classification of the images is performed. Different studies implement different methods, techniques and algorithms in these four steps to classify or detect the cashews.

Aran M. O et al. [16] used 500 samples of cashews from W180, W320, SW320, SSW, and B grades in the study. Wiener, Lucy, and regular filters were used for pre-processing. Features like colour, texture, shape, and size were first used individually, then two features together, and later three features together for classification. Random Forest, Multiclass, Regression, Multi-layer Perceptron and BPNN classifiers were implemented. A BPNN with 96.8% accuracy was obtained. Damaged and split cashews were not identified.

Shyna A and R. M. George [18] used the same samples as in [16]. In pre-processing, the study uses Weiner and Lucy filters for wavelet transform. The background removal is better with a genetic algorithm. Single features are not sufficient, so features like colour, texture, shape, and size were extracted for classification. Support Vector Machine and Back propagation neural network classifiers were applied and compared. The accuracy was 99.6% and 97.7%, respectively. Classification in real time is difficult when the speed of image/cashew on the conveyor belt is high. Damaged cashews were not identified. The study shows the use of three texture features like energy, homogeneity, and contrast is more efficient.

The authors [20] present a complete cashew grading system with hardware and software setup. 650 samples of WW180, WW240, WW320, and WW450 were used in this study. Tensor flow and the Inception model are used to train the model. The Raspberry Pi was used to integrate a camera, robotic action for actuation, and software. The speed was an issue of concern, but the solution was cost-effective at 90% the speed was an issue of concern, but the solution was cost-effective and the accuracy was at 90%. Damaged and split cashews were not identified. Zhang Lin et al. [4] used only shape for the classification of cashew nuts. There is a linear relationship between length and height, but no clear linear relationship between length and thickness. It's identified as a 19 mm wide circular sieve with 83.57% accuracy. A regression model is used. Split cashews were excluded from the study because their colour and texture were not extracted and were also damaged. Winifred Nadar and J.M. Kundargi [12] also classified the cashews based on only shape parameters-length, width, and thickness. A Bayesian classifier was used in the study, and it was observed that the method offered a reduction in cost and material resources. It also offers an automated, high-speed and cost-effective.

N.V. Ganganagowdar and H.K. Siddaramappa [17] implemented Multilayer perception-Artificial Neural Network for recognition and classification. The study extracted the colour and morphological features and achieved an accuracy of 88.93%. A. Sivaranjani et al. [21] presented a good framework for a cashew grading system that was based on computer vision. The optimization of deep CNN was discussed but not implemented. Further, in [25], the authors combined the computer vision framework with data augmentation. The study used 15 layers in CNN for classification of cashews, CashNet-15, to extract a greater number of features and achieved an accuracy of 97.7%.

A survey was carried out by Pratik K Patel et al. [6] on the cashew classification based on neural networks that extracted only the colour of the cashews. The classification accuracy was 80%, but the limitation of this model was that it was not applicable for a greater number of kernels. A fuzzy logic-based computer vision system was implemented for 1700 samples were used in the classification. An effective and efficient technique that provides an automated, non-destructive, and high-speed solution with an accuracy of 89%. But the speed was high. The shape of cashews, length, width,

thickness, colour reflection, and shadow were also extracted [8]. The colour as well as other morphological features were extracted for classification. In [8, 22], an improved classification model was developed that extracted cashew features such as color, texture, shape, and size to improve food quality.Matlab was used for simulation. Cashew nuts as well as areca nuts were classified. SVM and BPNN were implemented for classification and the accuracy obtained was 99.6%. Hardware was also designed for segregating the nuts. A review on BPNN classification for grading system highlights its importance in creating intelligent systems [14].

A cost-effective intelligent system was developed by Lalitha Saroja Thota et al. [7] using image processing and data mining techniques. Lab view was used for image processing and the WEKA toolkit for data mining. In image processing, a back propagation neural network was implemented and it provided an accuracy of 86%. This study dealt with limited samples and only colour was considered, not the length, width, and thickness of cashews. Vrushali Nagpure and Kavita Joshi [15] extracted features like texture, color, and shape for classification and applied the K-Nearest Neighbor algorithm and K-means clustering. This study identified defects with 87% accuracy. Another study in [23] extracted texture, color, and morphological features and applied a random forest classifier. It obtained 94.28% accuracy, but capturing the image with proper external lighting conditions was a challenge. Defect identification lacked accuracy, and weight and side view were not considered.

It is observed that classification techniques in cashew grading systems are based on computer vision. A study evaluated the performance of such systems [5]. The classification depends on the characteristics of the data. The features extracted are length, width, and thickness. It used techniques like MLP, Nave Bayes, KNN, Decision Tree, SVM, and Weka toolbox. The achieved accuracy was 76–86%, but the speed of detection was a challenge. [26] Proposed a five-category classification using image processing and deep convolutional neural networks such as inception-V3, ResNet50, and VGG-16.The sorting and grading accuracy of 95.1% is impressive. The performance of inception-V3 and ResNet50 was promising based on the measures of like specificity, precision, sensitivity, accuracy, and F1-Score.

From literature, it is observed that grading systems are used in identifying the quality of fruits [3]. The features extracted are color, shape, weight, size, and texture. Gaussian Mixture Model, Fourier's Separation Model, Support Vector Machine, Back Propagation Neural Network, K-Nearest Neighbor, and Feedforward Neural Network are the techniques used. The cashew grading system employs the same features and techniques. There are various areas where research on cashew grading has been performed. The machine that carries the cashews, its speed, and its working and cost are issues of concern. The supply chain management of the cashew grading system is not exploited. One study shows the application of RFID in tracking and monitoring processes. There are a lot of research studies that focus on workflow management, such as manufacturing industries, hospitals, automobile industries, etc., so that the processes become cost effective. The literature shows there are opportunities to examine and optimise the cashew workflows.

One more issue is the manual handling of the segregation and grading, identifying defective cashews and retaining quality cashews. The time consumed in this process is a major hurdle, and automation is the solution. Two aspects are important in this. One is the hardware and the other the software. As seen in literature, hardware deals with the kind of camera used, the way the images are captured, stored, and managed, and their resolution. The software has gained prominence in grading.

The features are extracted from the image based on which the classification of cashews into different grades is performed. The most commonly used features are color,texture, shape, morphology, and size of cashews. The colours are either white or cream. The shapes vary, like whole, splits, etc. The size also varies depending on the grades. There are studies that have considered only color, only shape, or only morphological features. There are also studies that consider these features in combination. The more the features used, more is the accuracy. There is also a study that considers the reflection and shadow in the images. Generally, the research shows grading of one category, but the study shows grading of five categories.

The survey shows that many techniques have been used to grade the cashews, most prominently image processing techniques. The pre-processing and classification techniques are implemented. Machine learning and deep learning algorithms are applied. Classifiers like Random Forest, SVM, back propagation in neural networks, multiclass regression, Bayesian, multilayer perceptron, feed forward neural networks, convolutional neural networks, K-Nearest Neighbor and deep neural networks are implemented. The classification accuracy varies for each algorithm between 76% and 99.6%. Cost-effective frameworks are developed. As machine-learning algorithms are used, the data set required to run these algorithms is large. The data is divided into training and testing data. At that time, data augmentation is performed to improve the classifier accuracy.

It is observed in literature that classification in real time is difficult when the cashews on the conveyor belt are high. Most of the time, damaged cashews and split cashews were not identified. A few studies proposed the technique but were not implemented. So, analysis of such techniques and methods was incomplete. The studies considered only a few kernels, whereas in real time, the kernels are huge in number. Additionally, speed of detection is a major challenge. The algorithm, when trained for a particular grade to recognise, fails to recognise other grades.

4. CONCLUSION AND FUTURE WORK

This study conducted a systematic literature review on the cashew grading system. Quality determination and classification of cashews based on the grades is a challenging task, that too in real time. Image processing with artificial intelligence, machine learning, deep learning, and computer vision techniques sorts and grades cashews with high accuracy. The focus must be on automating methods and extracting different features for the classification of cashew. As cashews to have high export value, a robust grading system for industrial scale along with high speed of computation is required. This would make the process less time-consuming, more efficient, and cost-effective.

Future work includes incorporating other techniques for identifying damaged and split cashews so that such cashews can be eliminated from the grading process.

5. ACKNOWLEDGMENTS

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