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Deep Learning-Based Soybean Grading: A Literature Review

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Abstract:
Soybeans (*Glycine max* L.) have emerged as a pivotal global food crop, prominently recognized for their high protein content and versatile applications.Thus, learning in soybean crops, delves into the state-of-the-art methodologies in machine learning (ML) and artificial intelligence (AI) applied to soybean grading. This review synthesizes literature and studies from 2018 to 2023, drawing from diverse online publications. Results highlighted Random Forest (RF) and Support Vector Machines (SVM) as the most frequently employed ML algorithms in soybean grading. The review underscores the achievement of high-accuracy soybean classification with RF and SVM. While the literature review successfully synthesizes existing knowledge, it emphasizes the untapped potential of AI in agriculture.

Keywords **—Support Vector Machine, Random Forest, Machine learning, Artificial intelligence, Food crop, Algorithm**

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I. INTRODUCTION

Soybeans play a crucial role in agriculture due to their ability to enhance soil fertility, provide a source of inexpensive protein, and withstand changing climates [1], [2]. They also contribute to the efficient use of lands and the productivity of subsequent crops [3]. Furthermore, soybeans have a significant impact on farm income, particularly when improved varieties are adopted [4]. Their diverse uses in the food, feed, and industry sectors further underscore their importance [5]. Quality grading is essential in the soybean industry to ensure the production of high-quality products and protect buyers from substandard produce [6]. This is particularly important in countries with significant soybean production, such as the United States, Brazil, Argentina, China, and India [3]. Various methods, including image analysis and machine learning techniques, have been developed to automate the quality assessment of soybean seeds, improving accuracy and efficiency [7]. These advancements in quality grading are crucial for the successful expansion of soybean cultivation and the sustainability of the soybean supply chain [8].

The significance of quality grading in soybeans is underscored by its impact on the soybean industry and the production of tertiary products [6]. Image analysis and machine learning techniques have been used to develop a method for quality grading, with high accuracy rates achieved [7], [9], [10]. The relationship between soybean chemical traits and tofu quality has also been explored, with the potential for predicting tofu quality based on these traits [11]. However, the sampling method during processing has been found to be more representative for seed quality assessment [12]. These studies collectively highlight the importance of quality grading in soybeans for both the industry and the production of soybean-derived products.

In addition to being processed into soy products and animal feed, soybeans are one of the major sources of vegetable oil. It is the most important agricultural product that China imports and a major worldwide economic crop [13]. Given that they are a crop with high fat and protein content, short shelf life, and difficulty in storing, soybeans are considered short-lived seeds. Because of this global demand of soybean market increasing day by day we need to improved quality of soybean by using image processing and machine learning for better result than that of the manual inspection[14], [15]. According to [16], the length of storage period has a major impact on soybean seed viability since longer storage years cause the seed viability to decline quickly. In actual production, prolonged storage times for seeds might lead to problems like low yield and low germination rate. Conventional techniques for ascertaining the soybean crop year encompass chemical analysis and empirical identification [17]. When it comes to improper handling and how it affects its marketability, improper handling of grain that is stored can lead to spoiling and a loss of market grade. To avoid issues with grain storage, it is crucial to store grain at the right moisture level, monitor grain often while it's being stored, and control grain temperature. When moderate temperatures start to warm grain masses in the late winter, it is especially crucial to keep an eye on stored soybean [18]. It has long been known that soybeans may be used for both food and non-food purposes. Soybean protein is the plant-based protein source that most closely resembles the ideal dietary necessary amino profiles needed for both human and animal nutrition[19], [19], [20], [21], [22]. As a result, soybean production, acceptability, and consumption are increasing in non-traditional global locations. The global market for soybean seed is experiencing high demand due to factors such as population growth, the ongoing need for animal feed, and the wide variety of products made from soybeans [23]. These days, soybeans are the most important crop for oil and protein production. Their seeds are utilized in many industrial processes as well as for the production of edible oil and protein for use by humans and animals. Owing to consumers' growing interest in nutritious food, soybeans are being cultivated under organic systems more and more often, yielding excellent results [15]. Agriculture technology has become more sophisticated in recent years. Farmers can now collect and analyze enormous amounts of data about their crops, including weather trends, the state of the soil, and plant growth, thanks to the growing use of precision farming, decision-making based on data, and advanced data analysis using deep learning techniques and other artificial intelligence (AI) technologies. According to [24], farmers may enhance agricultural yields, decrease waste, and boost profitability by utilizing AI to optimize farming operations article on predictive analytics provides support for this idea, stating that artificial intelligence (AI) may be utilized to forecast agricultural yields by analyzing data on weather patterns, soil properties, and crop growth. This can help farmers make informed decisions about planting, fertilizing, and harvesting their crops [25].

Several agricultural sectors, including yield prediction, weed and disease detection, water and soil management, animal production, etc., have used machine learning (ML) and its variations. A growing number and quality of agricultural goods have been produced thanks to machine learning approaches [26]. All of it can be monitored by machine learning algorithms, which can also provide farmers with a precise image of the harvest's quality prior to it entering the processing plant. Crop illnesses also reduce productivity. Therefore, using computer vision or machine learning to detect, diagnose, and notify farmers of issues is also very helpful [27]. Applications in computer vision, machine learning, and the Internet of Things (IoT) can assist farmers and related industries become more profitable by increasing output, improving quality, and eventually raising both [28].

Through that, this review aims to synthesize the related literature and studies covered from 2018-2023. The selection of the studies came from different online publications. The rest of the paper is organized as follows. Related studies about soybean grading are discussed in section II. Methods for synthesizing are presented in section III. Followed by the discussion of the results in section IV and concluding remarks are given in section V. Lastly, the researchers recommendations in section VI.

A. *Limitation of Traditional Soybean Grading*

Traditional soybean grading techniques have limitations and challenges. According to[29], traditional method used for disease scoring scale to grade the plant diseases is mainly based on naked eye observation by agriculture expert or plant pathologist. In this method percentage scale was exclusively used to define different disease severities in an illustrated series of disease assessment keys for field crops.The assessment of plant leaf diseases using this approach which may be subjective, time consuming and cost effective. Worldwide researchers are working on designing such automated systems for different type of fruits, grains etc. However, in case of Soybean, up until now we are successful in cleaning, sorting, color detection, and also, through various image processing techniques and algorithms researchers could detect the anomalies present in grain sample[30].

B. *Proposed Solutions to Traditional Soybean Grading*

To address the limitations and challenges in soybean quality grading, Image processing and machine learning technique are modified to use the quality grading of soybean seeds. In the study of [29], [31], [32]. They have utilize image processing and classification techniques to quantify disease severity. They propose a technique for automatically quantifying the damaged leaf area using k means clustering, which uses square Euclidian distances method for partition of leaf image.For grading of soybean leaf disease which appear on leaves based on segmented diseased region are done automatically by estimating the ratio of the unit pixel expressed under diseased region area and unit pixel expressed under Leaf region area. Comparative assessment results showed a good agreement between the numbers of percentage scale grading obtained by manual scoring and by image analysis The result shows that the proposed method is precise and reliable than visual evaluation.

C. *Usage of Artificial Intelligence to Soybean Grading*

As one of the top five food crops in the world, soybeans (*Glycine max* L.) are now the most significant oilseed crop. Because of their high protein content, soybeans are a popular feed option for animals, and its oil is utilized in both industrial and personal purposes. Global demand for soybeans is still rising, but environmental stresses brought on by climate change are also getting worse and more pervasive [18]. Consequently, the review of [33] describes the state of the art of deep learning applied to soybean crops at this time, outlining the primary developments made thus far and—more importantly—offering a thorough examination of the primaryobstacles and unmet research needs. It was discovered that, in contrast to the highly diverse settings of training data, artificial intelligence models frequently perform poorly in real-world scenarios. Agriculture might undergo a revolution thanks to AI, but there are still a lot of issues that need to be resolved.[11], [34], [35], [36], [37], [38]

It is challenging to assess the quality of seeds in real time because of their tiny size, irregular form, and high necessities for sorting accuracy [2], [4], [33], [39], [40]. For this reason, [41]produced a lightweight CNN that can identify abnormalities in soybean seeds at various sizes.

II. METHODOLOGY

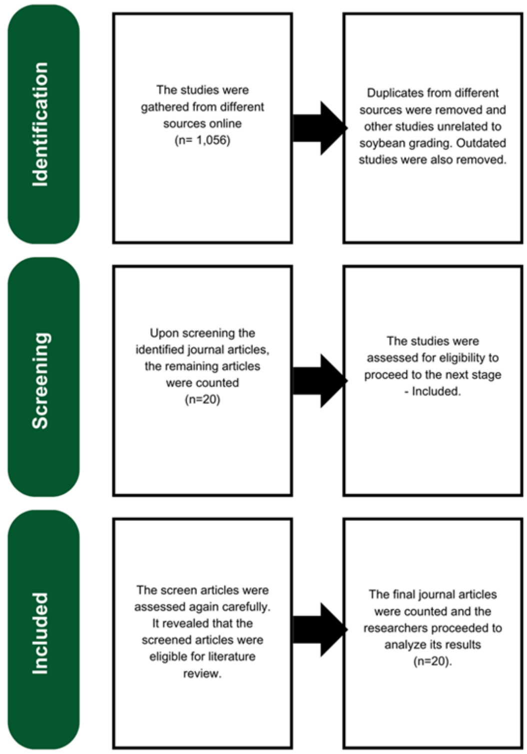

Fig. 1 Flowchart for the Selection of Studies

A. Data Collection

The literature review was carried out by searching on different publications such as IEEE Xplore, Scopus,Tayolor& Francis Online, Science Direct, ResearchGate, MDPI, IOPScience, and Frontiers. The following words were searched in the titles of abstracts of published studies: “ML”, “Soybean”, “CNN”, “AN”, with other additional keywords such as “Classification”, “Outcome Prediction” and “Quality Grading.”

B. Limitations of Traditional Soybean Grading

Each article was rated according to its title and abstract as part of the screening evaluation. To ascertain if each detected record might be included in the systematic review, a thorough investigation was conducted on each one. In order to make a more focused selection, some records have to be excluded based on predetermined criteria. At the same time, attempts were made to get reports related to these records, albeit not all of the reports were retrieved successfully. The retrieved reports were then subjected to a comprehensive eligibility assessment, which resulted in the exclusion of certain reports for the reasons specified in the study protocol. For the full examination of soybean grading using machine learning, a thorough selection of pertinent studies is ensured by the systematic screening method.

III. RESULTS

The results of this literature review were presented in tabular form for it to be more meaningful. The researchers selected this format for a better understanding of each studies. Table 1 shows the synthesized studies included in the review.

TABLE I
SYNTHESIZED STUDIES

LeadAuthor	Date	Title	Area of Focus	Analysis
Jitanan	2019	Quality Grading Of Soybean Seeds Using Image Analysis	Categorize	Support Vector Machine (SVM)
Medeiros	2020	Interactive Machine Learning For Soybean Seed And Seedling Quality Classification	Classifying	Linear discriminant analysis (LDA), Random Forest (RF), and Support Vector Machine (SVM)
Yende	2019	Quality Analysis And Grading Of Soybean Using Machine Learning	Grading	Artificial Neural Network (ANN)
Baek	2019	Rapid Measurement Of Soybean Seed Viability Using Kernel-Based Multispectral Image Analysis	Categorize	Near-Infrared (NIR) Spectroscopy and Hyperspectral Imaging (HSI)
Sonawane	2019	A Literature Review On Image Processing And Classification Techniques For Agriculture Produce And Modeling Of Quality Assessment System For Soybean Industry Sample	Grading and Assessment	SVM and Probabilistic Neural Network (PNN)
Hendrawan	2021	Classification Of Soybean Tempe Quality Using Deep Learning	Classify	Convolutional Neural Network (CNN)
Yoosefzadeh-Najafabadi	2021	Application Of Machine Learning Algorithms In Plant Breeding: Predicting Yield From	Assessment	Multilayer Perceptron (MLP), Support Vector Machine (SVM), and Random

		Hyperspectral Reflectance In Soybean		Forest(RF)
Herrero-Huerta	2020	Yield Prediction By Machine Learning From Uas-Based Multi-Sensor Data Fusion In Soybean	Classify	Random Forest(RF)
Gava	2022	Soybean Cultivars Identification Using Remotely Sensed Image And Machine Learning Models	Classify	Artificial Neural Network (ANN), Random Forest(RF), Support Vector Machine (SVM), Radial Basis Function Network (RBF), Decision Tree Algorithms J48 (DT) and Reduced Error Pruning Tree (REP),
Momin	2017	Machine Vision-Based Soybean Quality Evaluation	Classify	Developed AlgorithmUsing Front Lit and Back Lit Images
Aykas	2020	In-Situ Screening Of Soybean Quality With A Novel Handheld Near-Infrared Sensor	Assessment	NIR Spectroscopy
Krishna	2020	Soybean Crop Disease Classification Using Machine Learning Techniques	Classify	K Nearest Neighbor (KNN), Naive Bayes, Decision Tree (DT), Neural Network Algorithms
Alves	2018	Estimating Soybean Yields With Artificial Neural Networks	Evaluation	Convolutional Neural Network (CNN)
Falk	2020	Computer Vision And Machine Learning Enabled Soybean Root Phenotyping Pipeline	Classify	Automatic Root Imaging Analysis (Aria) Root Phenotyping Software And Convolutional Neural Network (CNN)

Durai	2022	Smart Farming Using Machine Learning And Deep Learning Techniques	Classification and Prediction	Random Forest (RF)
Zhao	2022	Real-Time Recognition System Of Soybean Seed Full-Surface Defects Based On Deep Learning	Classify	Convolutional Neural Network (CNN)
Amaral	2022	Artificial Neural Network For Discrimination And Classification Of Tropical Soybean Genotypes Of Different Relative Maturity Groups	Classification	Artificial Neural Network (ANN)
Bevers	2022	Soybean Disease Identification Using Original Field Images And Transfer Learning With Convolutional Neural Networks	Classification	Convolutional Neural Network (CNN)
He	2023	CNN Classification Of Soybeans With Storage Time Based On Near Infrared Spectroscopy	Evaluation	Fusion Of NIR Spectroscopy Analysis andConvolutional Neural Network (CNN)

A. Discussion

To the best of our knowledge, this is the first attempt to synthesize the studies using ML and AI algorithms in soybean grading. The number of identified ML and AI algorithms demonstrates the level of interest and effort dedicated to the application of ML in agricultural settings.

Based on the synthesized studies, it revealed that the ost frequently published type of ML in soybean grading is Random Forest (RF) followed by Support Vector Machines (SVM) classifiers. Random forest (RF) is a versatile and user-friendly machine learning technique that consistently yields excellent results, even in the absence of hyper-parameter adjustments. Random Forests is an ensemble bagging technique whereby numerous decision trees are combined to obtain final modeling of the results. This process combines both bootstrapping and aggregation. The key advantage of this approach is that it can be used for either classification or regression problems. Although RF can provide higher diagnostic accuracy and reduce variance without increasing bias, the operating time might be too long.

Support Vector Machine (SVM), on the other hand, is a supervised technique that finds a hyperplane to divide classes with the largest possible margin by projecting data into a higher dimensional resource space. A hyperplane's resilience to extreme values reduces incorrect classifications significantly. Thus, these two algorithms in machine learning are good to use for future reference of other researchers who want to explore the same field.

Other common ML algorithms were also identified but not frequently, there are also several studies using neural-network algorithms such as CNN and ANN. Convolutional Neural Networks (CNNs) are tailored for image-related tasks, employing convolutional layers to automatically discern features within images, making them highly effective for pattern recognition and object detection. They are widely utilized in computer vision applications due to their specialization in extracting meaningful information from visual data. On the other hand, Artificial Neural Networks (ANNs) are general-purpose and versatile, comprising layers of interconnected nodes. While ANNs can handle various tasks like classification and regression, they lack the innate ability of CNNs to automatically learn and extract features from raw image data. ANNs may necessitate feature engineering for optimal performance on specific tasks, making them less seamless for image-related applications compared to the specialized architecture of CNNs.

In summary, the literature review provides a concise overview of the evolving landscape of soybean quality grading, stressing the transformative potential of image processing and machine learning for improved accuracy and efficiency in soybean cultivation and supply chain sustainability.

B. Strength and Weakness

This extensive literature analysis stands out for its many accomplishments, especially its resource-constrained capacity to combine a sizable body of research on the interface of machine learning and soybean grading. The researchers skillfully selected and evaluated papers despite the restricted supply of research resources, demonstrating their commitment to investigating the subtleties of soybean grading in the context of artificial intelligence.

The careful consideration given to the wide range of techniques employed to the dataset is one admirable feature of this assessment. This technique not only reflects the researchers' commitment to completely knowing the subject matter but also allowed them to reach meaningful findings regarding the comparative efficacy of various algorithms in the soybean grading context.

However, it is essential to identify the constraints of the investigation, since they are critical in setting the outcomes in context. The biggest problem found is the absence of resources that handle soybean grading specifically and don't rely on conventional and classical categorization techniques. Despite being beyond of the researchers' control, this restriction raises questions regarding possible mistakes made when taking machine learning algorithms into account. The selection of research included in the review may have been impacted unintentionally by the lack of alternative sources, which might have an effect on the diversity and comprehensiveness of viewpoints represented.

Moreover, there is reason for worry over the possible underutilization of machine learning techniques. The scope may have been narrowed as a result of the restricted number of sources that were available, maybe ignoring some algorithms that could have provided insightful information on soybean grading. This acknowledged constraint highlights the necessity of doing more research to investigate a wider range of machine learning techniques in order to gain a more thorough grasp of their suitability for use in soybean grading scenarios. Even though this evaluation of the literature does a great job of synthesizing data under resource restrictions, it is important to acknowledge the inherent limitations associated with the lack of alternate sources.

IV. CONCLUSION

Based on the results, it was discovered that high-accuracy soybean classification is achievable using Random Forest (RF) algorithm and Support Vector Machine (SVM). By effectively combining the many investigations, the researchers have achieved their targeted goals. After all, there is yet unmet potential for AI across agricultural sectors. Despite the expanding number of published ML algorithms, there is limited evidence of their impact on soybean grading. More evidence addressing external and internal validation helps drive the transition toward a broader, more robust, and safer adoption of AI.

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