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Grading of Mangoes Using Deep Learning

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ABSTRACT: The quality grading of mangoes is a crucial task for mango growers as it vastly affects their profit. However, until today, this process still relies on laborious efforts of humans, who are prone to fatigue and errors. To remedy this, the paper approaches the grading task with various convolutional neural networks (CNN), a tried-and-tested deep learning technology in computer vision. The models involved include Mask R-CNN (for background removal), the numerous past winners of the ImageNet challenge, namely AlexNet, VGGs, and ResNets; and, a family of self-defined convolutional autoencoder-classifiers (ConvAE-CIFs) inspired by the claimed benefit of multi-task learning in classification tasks. Transfer learning is also adopted in this work via utilizing the ImageNet pretrained weights. Besides elaborating on the preprocessing techniques, training details, and the resulting performance, we go one step further to provide explainable insights into the model's working with the help of saliency maps and principal component analysis (PCA). These insights provide a succinct, meaningful glimpse into the intricate deep learning black box, fostering trust, and can also be presented to humans in real-world use cases for reviewing the grading results.

I. INTRODUCTION

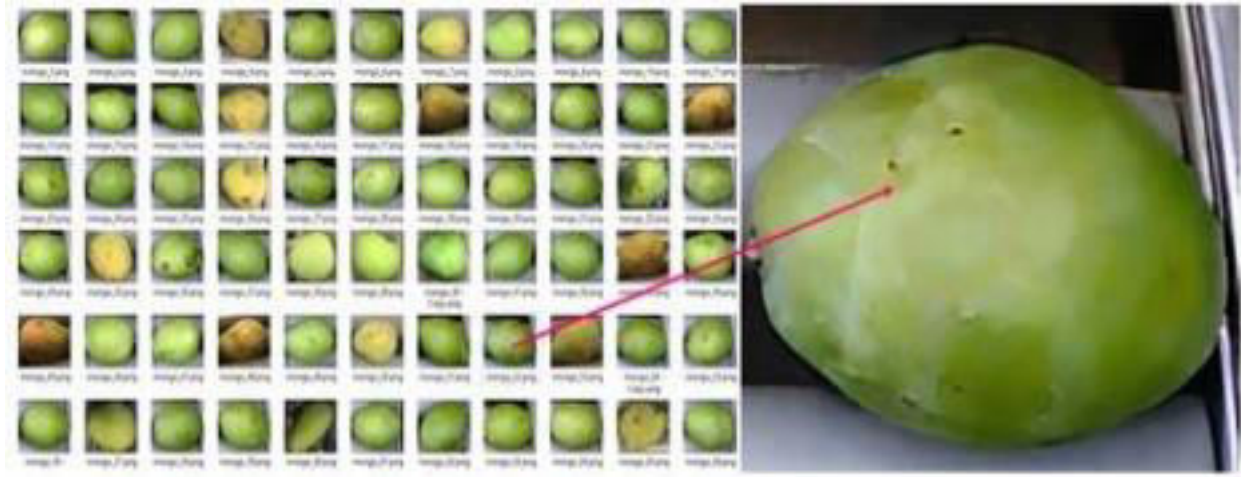
Mangoes are a lucrative fruit widely grown in tropical and sub-tropical regions of the world. Its enticing aroma, flavorful pulp, and high nutritional value attract numerous mango lovers from worldwide, contributing enormous economic benefits to mango growers and exporting countries. It is worth emphasizing that the economic value of a mango fruit depends heavily on the aesthetics of its appearance; the best-looking ones are reserved for export, the lesser ones for domestic consumption, and the worst ones for further processing to make canned fruit or jam. However, the quality grading of mangoes is a laborious process which, up until now, almost fully relies on human inspection. This time-consuming process not only shortens the profitable shelf life of the fresh fruits, but is also prone to human errors that could lead to losses. Therefore, this work, coupled with the Taiwan AI CUP 2020 competition, strives to bring the tried-and-tested deep learning technology in computer vision, namely the various convolutional neural networks (CNNs), to the rescue of mango growers, helping them finish the grading task accurately and effortlessly.

II. RELATED WORK

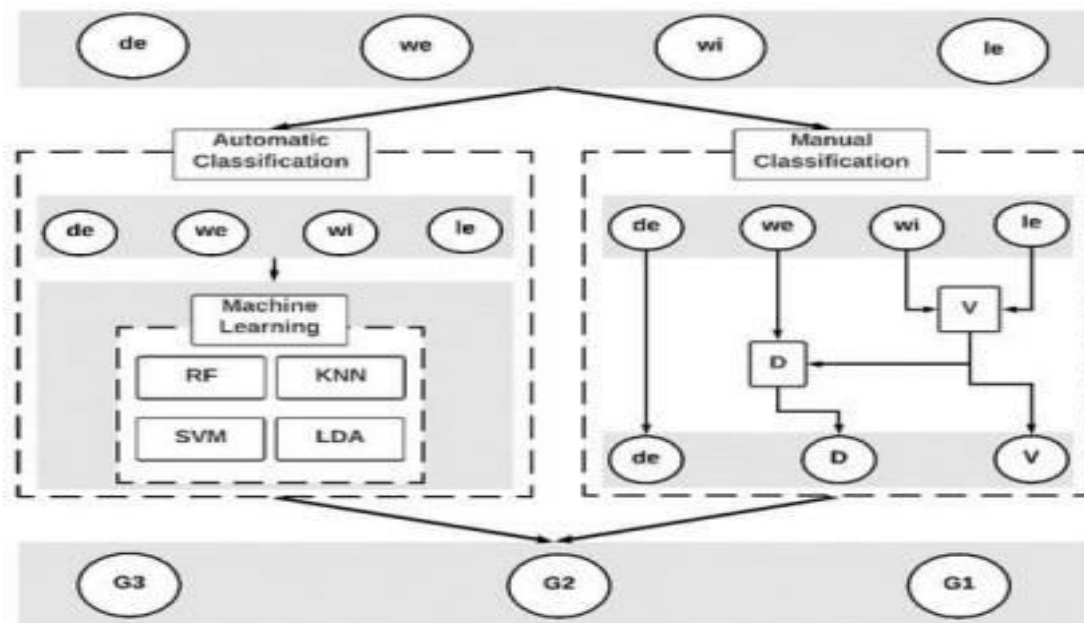
The recent decade has seen a sizeable body of research on agricultural applications of deep learning techniques, more specifically, the various CNN-based architectures. However, the majority of works investigated land-use classification, or crop type detection, from aerial/satellite images; and, fruit counting, or weed detection, from images taken from closer distances. Another series of efforts paid attention to plant disease detection, but all of them examined plant leaves rather than fruits. Notwithstanding, if we narrow down the scope of the study to the quality grading of fruits, there were almost no deep learning-based solutions proposed. The two previous works concerning the grading of mangoes, involved no deep learning, and relied substantially on the size, shape, and color features computed from meticulously-taken images; as well as completely rule-based grading criteria. More recent research on other types of fruits though experimented with several classical machine learning methods (e.g., KNN, SVM)

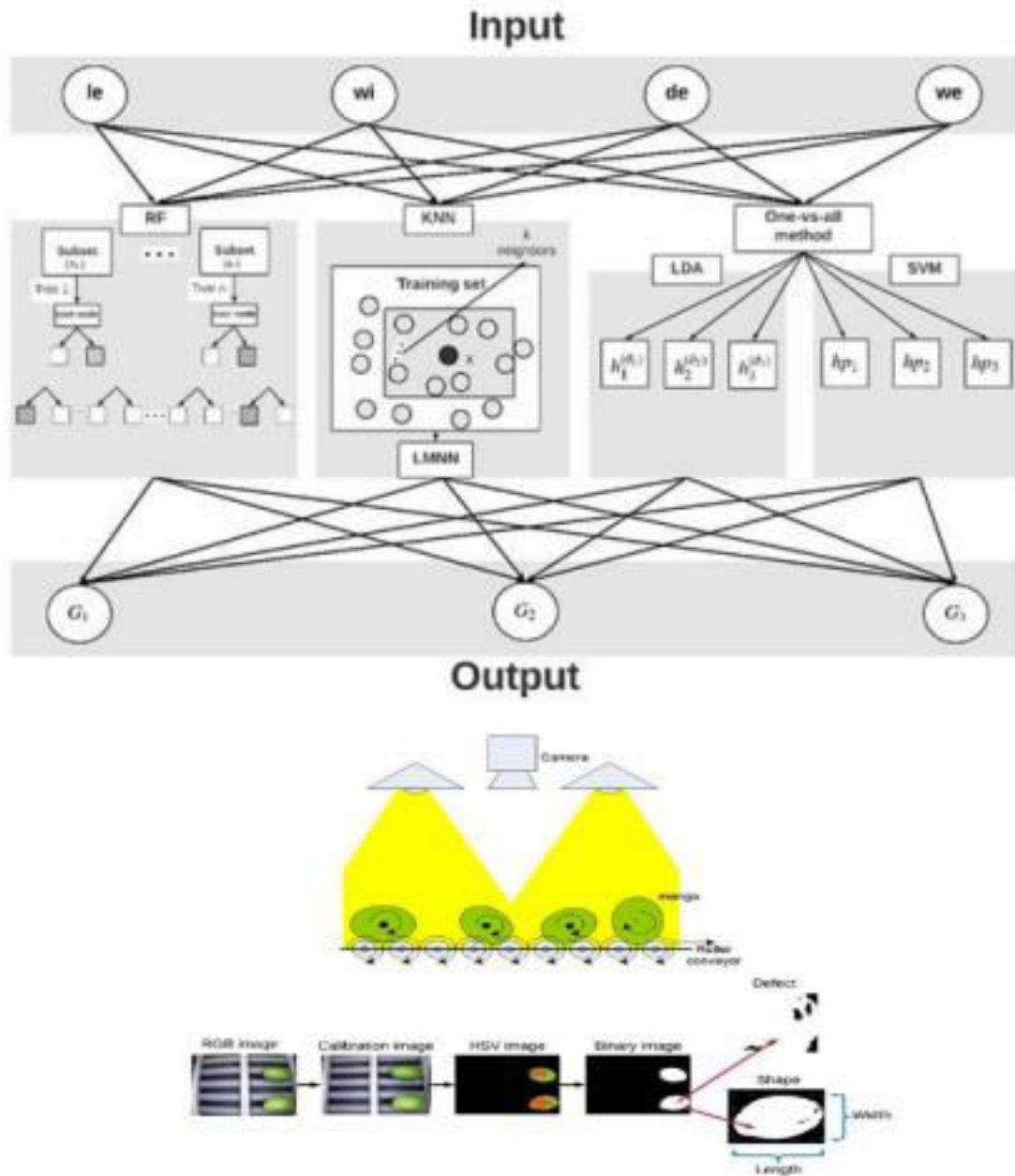
III. METHODOLOGY

The internal quality of mango is a nonlinear function of features such as length, width, defect, and weight. The quality of mango is graded based on the local standard or international standards (Global GAP), which are implemented easily to classify according to each feature, but it is difficult to grade the fruits with



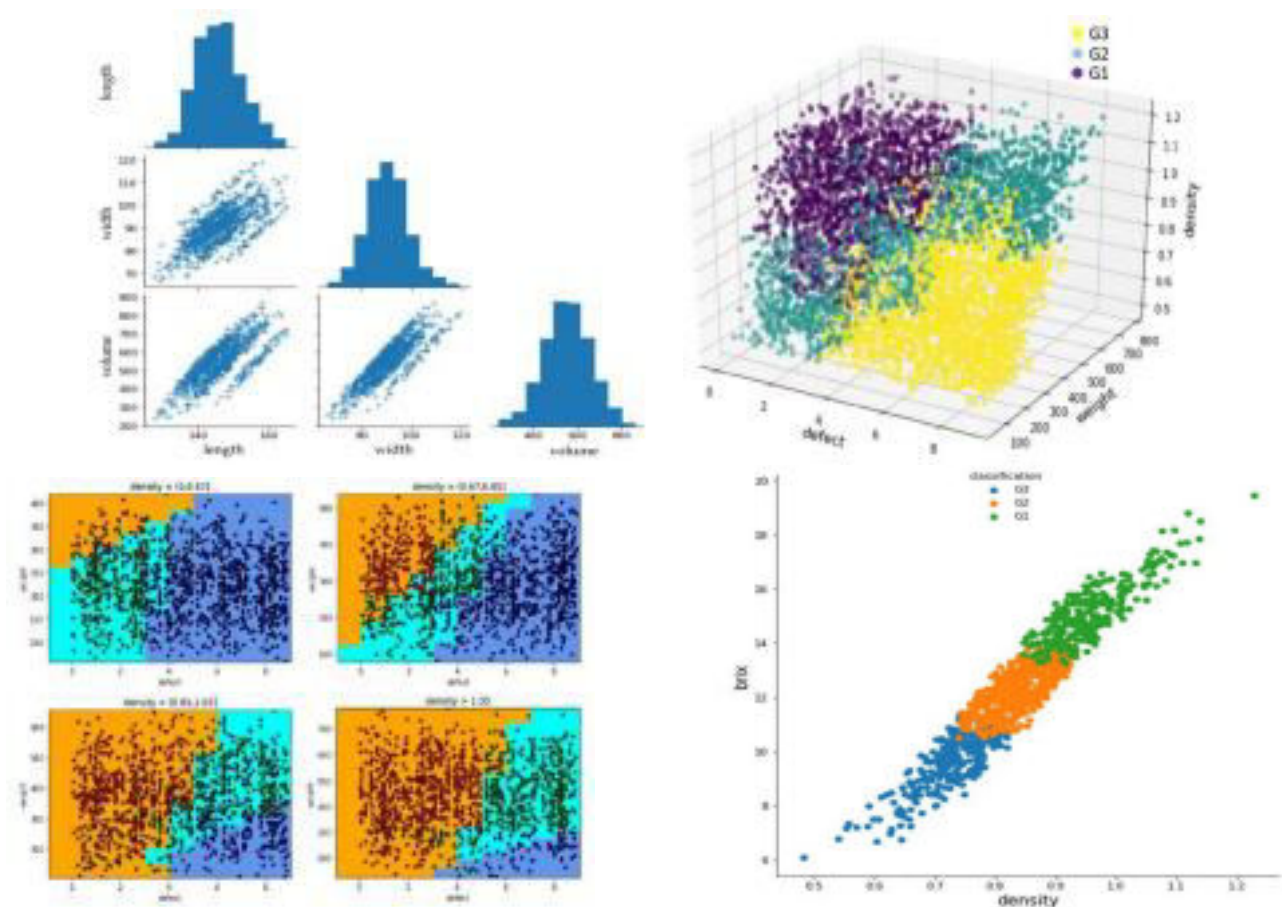
combination of different features. The relationship of features is found in several methods such as regression, statistical, and machine learning. In this paper, ML is proposed to grade the internal quality of mango, because of its strong ability in calculating and analyzing repeated problems. The papers looked particularly closely at the application of supervised ML techniques to mango classification. Hence, in this study, four supervised learning algorithms such as SVM, LDA, KNN, and RF are proposed for grading and sorting mango. The trained models are based on the sampling mango surveys in many orchards in Vietnam. In detail, the samples of mango are randomly selected, and then their types are determined by evaluating standards accurately.



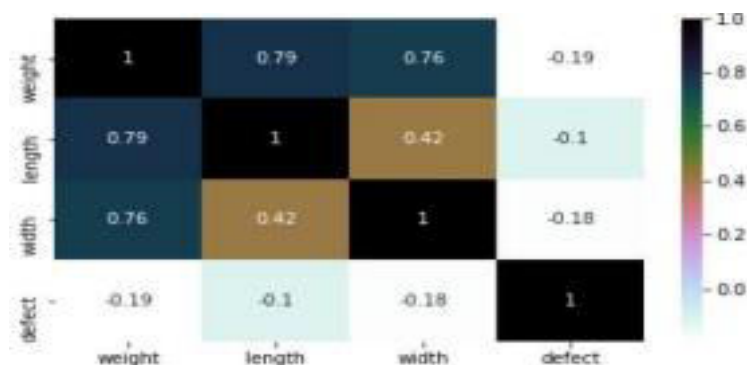


IV. EXPERIMENTAL RESULTS

These experiments used 4983 mango samples harvested from November to June to meet the requirements of standards. They were measured accurately by the sorting system of the vision machine and weight. Acquired data from grading work was important and necessary to predict exact grades. The data was collected from the vision machine to get length, width, and area of the defect. This data combined the weight of each mango measured based on load-cell. The parameters of ML were determined to grade the mango quality employing input and output sets. The features of the original data set were collected by image processing and weight. Besides, their labels were classified by the manual classification system. Training and validation data from 90% of the original data were separated by using the NCV method. Besides, testing data accounted for the remaining 10% of the original data. The ML models were implemented to grade the mango quality based on its external features and weight. The models gave the results for 3 types of mangoes as good grade (G_1), medium grade (G_2), or bad grade (G_3). Besides, these models also showed the relations between the input and output with different features. The models predicted the quality based on the qualification standards automatically instead of the manual



evaluation. The credibility of models was confirmed by the empirical method using the confusion matrix to evaluate the performance of models. The accuracy of the image processing part was evidenced by the experimental results in which actual and estimated values are compared. The data was measured actually in with length, width, and area of defect by Mitutoyo’s tools with an accuracy of 0.05 mm. The testing data checked the final solution in order to confirm the actual predictive work. Besides, the weight was the subset of testing set measured by electronic scales with an error of 0.01 g. Thereby, the volume (V) of the mango was determined by the overflow method with 1000 mL glass jar with accuracy 0.4 mL. Each feature of mango such as weight, width, and length was measured 10 times to calculate the expected value. From the above sections, the models are recommended to predict types of mangoes. There are four models to apply and implement such as *RF*, *LDA*, *SVM*, and *KNN* fitted by data.



The process of extracting dimensions and defects of mangoes

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