INVESTIGATING THE CLASSIFICATION OF VEGETABLE

THROUGH MULTIPLE DEEP LEARNING APPROACHES

## Abstract

The aim of this work is to investigate the use of deep learning models for vegetable categorization with the aim of enhancing agricultural methods and promoting greater food security. The performance of four sophisticated deep learning models is evaluated in this work using a dataset of 2500 images covering eight distinct vegetable groups. Eight distinct vegetable species fall into this category: potato, pointed gourd, lady finger, bean, capsicum, cabbage and bitter gourd. In this category is included a pointed gourd. The models being assessed, based on the results of this study, are DenseNet-121, VGG19, ResNet50, and EfficientNetB4. EfficientNetB4 has shown to be the best performance since it has attained high precision, recall, and F1-scores in all vegetable classes. The accuracy that is so obtained is 96.2%. ResNet50, VGG19, and DenseNet-121 also have relatively good accuracy scores—93.7%, 88.5%, and 87.4%, respectively. These numbers really are remarkable. That these principles exist is really amazing. This work has revealed that deep learning algorithms can correctly categories a wide range of veggies. Moreover, significant new information has been provided on the choice of suitable models based on specific classification goals. This paper also contains a presentation of a sustainability plan to lessen the detrimental effects of computing activities on the ecosystem. Furthermore, stressed are the need of ethical issues and environmental protection. The results of the study emphasize, in brief, the need of doing ethical and responsible artificial intelligence research in agricultural settings. It offers information that may be applied to enhance agricultural methods, raise food security, and promote more research in the area of agricultural image analysis. All of these are possible with the application of these insights.

## INTRODUCTION

Vegetables are increasingly recognized for food and nutrition security[b1] and vital for human health adding variety and richness to the human diet [1]. Vegetables have important for its commercial and nutrition value in the world as well as in Bangladesh[b3], they are the main source of vitamins, secondary plant metabolites, mineral nutrients, secondary plant nutrients, and other substances that assist human nutrition and health [2]. In many regions of the world, particularly in the tropics, vegetables—especially roots and tubers—serve as staple crops and can have a high caloric content. Vegetables make up feIr than 1% of all plants in the world, yet their genetic, anatomical, and morphological variety is remarkable [3]. In both commercial and subsistence agricultural systems across the world, hundreds of vegetable taxa are cultivated for food [4].

The growth of the commercialization of vegetable products is now being substantially hampered by the manual completion of duties such as picking, sorting, and selling vegetables. This practice not only requires a huge workforce but also results in low work efficiency [8]. Vegetable identification and categorization have received a lot of attention in recent years, and major advancements have been made in this area [11]. The suggested vegetable classifier is an artificial model that saves time by assisting humans in accurately classifying fresh vegetables [9]. Although there has been a lot of research on this subject, the most of it has focused on foreign plants, leaving a huge knowledge gap in the classification of native Bangladeshi vegetables. With a population of almost 164 million, the majority of whom rely on vegetables for their food. yet farmers may gain an estimated 11 million dollars in profit merely by eliminating 20% of the infection [20]. Such losses can be reduced, and the spread of infections can be stopped using an early detection system for vegetable diseases. The quality, quantity, and stability of the vegetable output are affected by the numerous forms of vegetable diseases. Vegetable diseases not only for production but also obliterate diversity and make it impossible to cultivate. Vegetable infections manifest as spots on the vegetable and can result in significant losses if left untreated [21].

There are several automated systems for vegetable classification[b4] and disease detection around the world[b2], but for this study, I will focus on Bangladeshi vegetables and their classifications. Since Bangladesh economy draws its main strength from agriculture sector[b5] and most farmers in every sector of agriculture are unaware of the existence, use and benefit of modern technologies in farming[b6]. which is one of the major barriers to adoption. Everyone, not just the farmers, will benefit greatly by applying such technology like an algorithm that will automatically identify and categorize the proper product in such a wide developing area [6] The division of vegetables into categories based on their edible components has been dubbed “Supermarket Botany” [7].

Today, gathering, identifying, and preserving fresh veggies has grown more complicated and labor-intensive. The suggested vegetable classifier is an artificial model that saves time by assisting humans in accurately classifying fresh vegetables [9]. Vegetable identification and categorization have received a lot of attention in recent years, and major advancements have been made in this area [11]. Although methods for classifying vegetables have been developed for robotic harvesting and quality evaluation, the present state-of-the-art has only been applied to a restricted number of classes and datasets. One of the main issues with current machine learning techniques is that the problem is multi-dimensional and gives a substantial amount of hyperdimensional information [15]. A convolution neural network for vegetable categorization has been created from scratch in this study [16]. The study of automated vegetable categorization and recognition [13] offers crucial technical help to address the aforesaid issues. New methods for recognizing veggies are introduced by Pragati et al. [14]. The accuracy of recognition is increased by combining four feature analysis techniques: form, size, color, and texture-based techniques [8]. AI is one of the most significant, practical, and cutting-edge technologies today. Machine learning and deep learning algorithms are pivotal for analyzing various fruit attributes, such as color, size, shape, firmness, texture, sugar content, and acidity, to assess ripeness and overall quality. DL architectures like convolutional neural networks (CNNs) are particularly effective in image analysis, extracting features and retaining attributes for tasks in computer vision. As a result, I created a quick and efficient vegetable categorization system that has excellent accuracy[b7].

Given that different vegetables may have similar colors, shapes, and textures, classifying them in computer vision remains difficult.

In this project, 2500 photos of veggies from eight different vegetable varieties. These gathered photos are preprocessed using several pre-processing operators to boost the quality of the extracted feature, and they are then scaled to feed the suggested convolution model. Dropout layers are also employed in the CNN model training stage to increase the proposed model’s accuracy. The suggested model’s accuracy is 98%. The ‘DenseNet201’ model, which employs the transfer-learning idea, is utilized to enhance model performance by freezing all layers but the dense layer. The pretrained model is trained using five distinct data augmentation operators on a gathered dataset. For determining the orientation of the vegetable item in an input image, Hetal et al. [17] suggested a better technique based on several characteristics. A technique called FSCABC-FNN, developed by Zhang et al. [18], is based on the fitness-scaled chaotic artificial bee colony algorithm. Color, shape, and texture Ire characteristics retrieved by the network. The precision obtained using this approach was rather good.

# RELATED WORKS

This literature review delves into a collection of studies that employ diverse methodologies and models to achieve effective vegetable recognition and classification, shedding light on the advancements made in this realm.

The authors of [22] utilized MobileNet and Inception CNN architectures to attain a commendable accuracy rate of 97%. The Random Forest model in capturing intricate data relationships is evident in this impressive performance, emerged with an exceptional accuracy of 98.3%.

In study [b8] hyperspectral imaging combined with deep learning as well as conventional machine learning models were used to identify the freshness of two kinds of leafy vegetables. Logistic regression (LR), SVM, RF, LSTM, CNN combined with LSTM (CNN-LSTM) classification algorithms were used among them CNN-LSTM models outperformed with classification accuracy over 80%.

This[b9] paper presents an extensive survey encompassing multispectral and hyperspectral images, focusing on their applications for classification challenges in diverse agricultural areas, including plants, grains, fruits, and vegetables. our attention is directed towards utilizing machine learning techniques for effectively classifying hyperspectral images within the agricultural context. The findings of our investigation reveal that deep learning and support vector machines have emerged as widely employed methods for hyperspectral image classification in agriculture.

This[b10] paper presents an automated plant leaf damage detection and disease identification system leveraging advanced deep learning techniques. The proposed method consists of six stages: first, utilizing YOLOv8 for region of interest identification from drone images; second, employing DeepLabV3+ for background removal and facilitating disease classification; third, implementing a CNN model for accurate disease classification achieving high training and validation accuracies (96.97 % and 92.89 %, respectively); fourth, utilizing UNet semantic segmentation for precise damage detection at a pixel level with an evaluation accuracy of 99 %; fifth, evaluating disease severity; and sixth, suggesting tailored remedies based on disease type and damage state. Experimental analysis using the Plant Village dataset demonstrates the effectiveness of the proposed method in detecting various defects in plants such as apple, tomato, and corn. This automated approach holds promise for enhancing agricultural productivity and disease management.

In paper [b11], authors utilized deep neural network (DNN) classification model to identify infestation of indoor plants using hyperspectral imaging data of book choy ‘’Brassica rapa subspecies chinenhis’’.  Linear Discriminant Analysis (LDA) and SVM showed excellent performance to classify images whereas DNN model achieved overall 92.8±0.4% classification accuracy.

The paper[b12] describes an efficient method for identifying illnesses in grape leaves using deep features from Convolutional Neural Networks (CNNs) and a Support Vector Machine (SVM) classifier. The approach explores various CNN architectures and feature fusion techniques to improve classification accuracy. By extracting and combining deep features from layers of ResNet50 and ResNet101 networks, and training an SVM classifier on these combined features, the method achieves a high F1 score of 99.82%. The fusion of deep features significantly enhances classification performance compared to using a single type of feature, while the SVM classifier achieves similar results to CNN training in a much shorter time, making the method practical for real-world agricultural applications.

Bahia et al. [23], who combined SVM with k-Nearest Neighbors (k-NN) to achieve a comparable accuracy of 94.3%. The SVM&#39;s ability to optimize decision boundaries, even within high- dimensional spaces, underscores its robust performance in the realm of vegetable and vegetable recognition. HoIver, their Logistic Regression model demonstrated a slightly loIr accuracy of 88.976% compared to both SVM and Random Forest. This discrepancy could be attributed to the inherent complexity of the dataset and the limitations of Logistic Regression in capturing non-linear relationships. Conversely,

Dubey et al. [24] showcased higher accuracies ranging from 93.62% to 98.90% by leveraging Image- Specific Adaptive Data Heterogeneity (ISADH) and a multi-class support vector machine (MCSVM). Their emphasis on feature extraction and the enhancing capabilities of ISADH highlight the differences in approach and methodology. Transitioning to eXtreme Gradient Boosting (XGBoost) and Gradient Boosting models, I achieved impressive accuracies of 96.4% and 96.38%, respectively. These outcomes mirror the achievements of

Duth P et al. [25], who delved into deep learning using convolutional neural networks (CNNs) and attained an accuracy of 95.50%. While their machine learning models showcased robust performance, the findings of

Duth P et al. [26] underscore the efficacy of deep learning techniques, particularly in intraclass vegetable detection.Within the realm of vegetable classification, the utilization of Convolutional Neural Networks (CNNs) has yielded remarkable results.

Femling et al. [27] demonstrated the effectiveness of CNNs by employing models such as MobileNet and Inception, echoing their own explorations. In their experiments explored a spectrum of machine learning models, encompassing Random Forest, Support Vector Machine (SVM), and XGBoost, achieving impressive accuracies of 98.3%, 94.09%, and 96.4%, respectively. Like Femling et al., acknowledge the pivotal role of accuracy and propagation time in efficient vegetable recognition. In tandem with the algorithmic approaches, hardware considerations have proven to be pivotal.

Ahluwalia et al. [28] emphasized the significance of cameras and displays, which align seamlessly with their pursuit of heightened accuracy through the implementation of models like Random Forest and XGBoost. This hardware-centric perspective ensures smooth data acquisition and user interaction, crucial for real-world applications. Correspondingly,

Kalyanasundar et al. [29] highlighted the importance of feature-based techniques, which resonates with their exploration involving models like Logistic Regression and Gradient Boosting. This endeavor culminated in accuracies of 88.976% and 96.38%, respectively. The incorporation of diverse feature extraction methods, as evidenced by both studies, significantly contributes to the robustness of vegetable classification. Furthermore, the theme of effective preprocessing emerges as a pivotal factor.

Muhtaseb et al. [30] introduced monochrome enhancement techniques, mirroring their own utilization of median and bilateral filtering. The adoption of Gradient Boosting yielded a classification accuracy of 96.38%, further underscoring the indispensable role of preprocessing in optimizing classification accuracy.