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Embarking on Comprehensive Exploration of Classification System of Fruits and Vegetables

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Abstract: This research thoroughly investigates the fruit and vegetable classification system, emphasizing exhaustive investigation. This research aims to comprehend, analyze, and document numerous facets of this classification with MobileNetV2. This investigation included a comprehensive literature review, field investigation, and review of relevant scientific documents. In this investigation, we divide the classification of fruits and vegetables into various levels, ranging from the most general, such as kingdom and division, to the most specific, such as order and family. We also investigate the central role of taxonomy in comprehending the evolutionary and phylogenetic relationships between various categories of fruits and vegetables. This research enables us to identify and understand the taxonomic relationships between multiple varieties of fruits and vegetables and classify them into the appropriate botanical families. In addition, we investigate the global diversity of fruit and vegetable varieties, emphasizing the significance of conservation and genetic management to preserve the diversity of these precious commodities. In their efforts to comprehend, manage, and maintain the genetic variety of fruits and vegetables, this research provides researchers, botanists, and producers valuable insights. The findings of this study indicate that investigating fruit and vegetable classification systems is a crucial step in comprehending and conserving this irreplaceable natural resource, which provides direct benefits to humans in the context of global biodiversity conservation. MobileNetV2 research results accuracy epochs(5) = 94.84%, epochs(10) = 98.35%, epochs(15) = 98.69%.

Keywords: Accuracy; Classification; MobileNetV2; Fruits and vegetables; Natural resource

INTRODUCTION

As a fertile tropical nation, Indonesia has long been recognized as one of the world's primary producers of fruits and vegetables. A tropical climate, year-round rainfall, and fertile soil have created an ideal environment for agriculture (Brown et al., 2021), (Soto-Gómez & Pérez-Rodríguez, 2022). As a consequence, Indonesia produces an abundance of various types of fruit and vegetables. Mangoes, bananas, oranges, durian, and rambutans throughout the archipelago thrive in lots. Each region has characteristics, such as Sumatra's renowned durian and Bali's delectable mango. Indonesia is also a significant producer of coconuts, utilized in various forms, including coconut milk, coconut oil, and coconut sugar. Vegetables play a substantial role in the flavorful cuisine of Indonesia. Vegetables (Misdaq & Chaouqi, 2023), (Won et al., 2023) such as beans, kale, eggplant, and chilies are frequently used in traditional dishes. Also increasing is the cultivation of organic vegetables, which is in response to market demand for healthful products. In addition to satisfying local needs, Indonesian fruit and vegetable production is exported to numerous countries worldwide. It has substantially contributed to the nation's economy and the growth of the agribusiness sector. Aside from this, the diversity of Indonesian fruits and vegetables also contributes to culinary diversity, allowing Indonesians to experience a variety of flavorful and nutritious dishes. Several obstacles must be addressed, including climate change, sustainable resource management, and infrastructure improvements, to guarantee the continued production of abundant fruits and vegetables in Indonesia. Indonesia can continue to be one of the world's foremost producers of fruits and vegetables and promote sustainable agriculture (Oliveira et al., 2023), (Xiang & Zhang, 2023), (Gomes et al., 2023), (Facchini et al., 2023) for a brighter future with the proper attention and effort.

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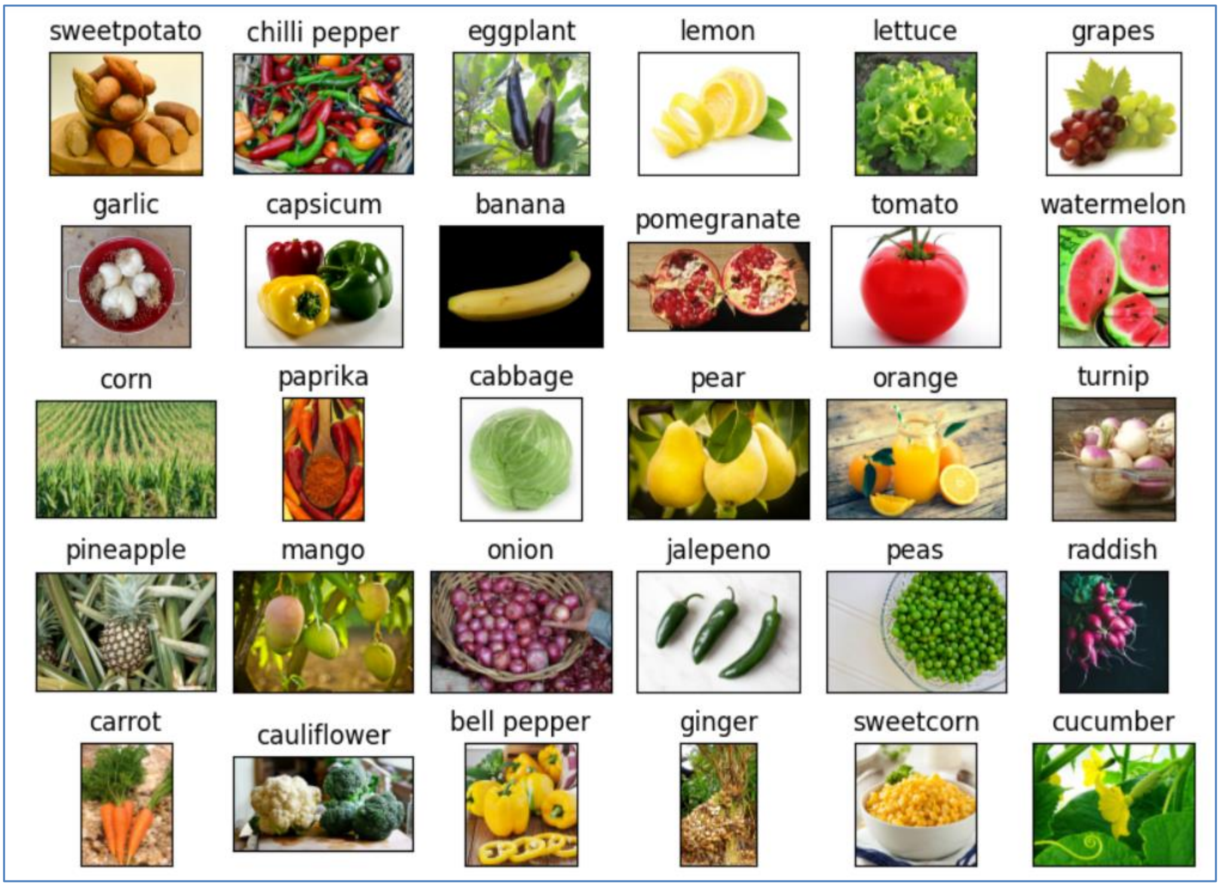

Fig. 1. Fruit and Vegetable
Source: Kaggle

The dataset depicted in Figure 1 has been employed in this study to facilitate the classification process of fruits and vegetables. Utilizing these datasets is crucial in guaranteeing the efficacy of training and evaluating classification models. The dataset comprises a collection of 3958 photos encompassing 36 distinct categories of various fruits and vegetables. The information in this context covers special classes corresponding to certain fruits or vegetables, serving as a valuable resource for instructing computer models on distinguishing between different types. The dataset depicted in Figure 1 was obtained from Kaggle, a collaborative data-sharing and resource platform offering diverse datasets for academic endeavors. Including a wide range of fruit and vegetable categories inside the dataset is crucial for facilitating accurate and effective classification by the model. This approach enables the model to accurately reflect the diverse fruit and vegetable varieties in real-world scenarios. Utilizing the extensive and varied dataset, the study successfully generated a dependable classification model that exhibits a notable proficiency in identifying diverse categories of fruits and vegetables. This achievement holds significant potential for practical implementation within image processing and agricultural sectors.

The study "A Comprehensive Investigation of the Classification System for Fruits and Vegetables" involves the utilization of the MobileNetV2 (Sutaji & Yıldız, 2022) algorithm to classify fruits and vegetables. This study utilizes MobileNetV2 (Shamrat et al., 2023), (Toğaçar et al., 2021) as the primary methodology for comprehending and categorizing diverse varieties of fruits and vegetables, relying on their visual representations or visuals. This research aims to comprehensively investigate existing classification systems and explore the capabilities of algorithms like MobileNetV2 in accurately discerning and distinguishing a diverse range of fruits and vegetables. MobileNetV2 has gained significant popularity in image classification due to its capacity to generate efficient and practical models well-suited for mobile device deployment and high-performance scenarios. This study seeks to attain high accuracy in classifying diverse fruit and vegetable varieties by employing MobileNetV2 (Indraswari et al., 2021). Throughout the study, the model underwent training using several datasets comprising representative photos of fruits and vegetables. Subsequently, the model's performance was evaluated by subjecting it to various datasets for testing purposes. The anticipated outcomes of this study are expected to make a significant scholarly contribution to the comprehension of fruit and vegetable classification systems. Additionally, the study aims to

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investigate the viability of employing the MobileNetV2 (Dlamini et al., 2023) algorithm in practical contexts, such as the automated identification of fruit and vegetable varieties in market settings or the automated sorting processes within the agricultural sector. Furthermore, this study can serve as a foundation for future computer vision and image processing advancements, explicitly targeting the comprehension and identification of organic entities such as fruits and vegetables. In the technological era, fruit and vegetable classification research has become essential. The ability to distinguish between fruit and vegetable varieties has implications for agriculture, dietary management, and resource management. This investigation is focused on developing innovative classification systems. How can we optimize the architecture of artificial neural networks to classify fruits and vegetables with the utmost precision? (First Research Question). How does the use of epoch affect the accuracy of fruit and vegetable classification? (Second Research Question).

LITERATURE REVIEW

This literature review section aims to provide a comprehensive overview of prior scholarly investigations about classifying fruits and vegetables. This literature review introduces the theoretical framework and findings that provide the foundation for the subsequent research. Automatic fruit classification is an intriguing retail and fruit industry problem. An automated fruit classification system using the Enhanced Tunicate Swarm algorithm with Deep Learning is proposed in this study. This technique uses three Deep Learning models and XGBoost to recognize fruit varieties better. MobileNetV2 accuracy 95.68 (Alharbi et al., 2023). The previous two decades have seen more hyper-spectral scanning studies, especially in horticulture. This scan measures fruit, vegetable, and mushroom quality factors well. AI and future issues are also covered in this essay (Wieme et al., 2022). This research employs a single-shot multi-box detector with MobileNetV2 architecture to produce Kiwi Detector, an Android app that rapidly and accurately detects garden kiwi fruit. The 8-bit quantization method reduces model size and speed detection. MobileNetV2 has a high detection rate (90.8%) for field kiwi fruit production estimation (Zhou et al., 2020). This study proposes identifying fruit photos using MobileNet deep learning techniques. MobileNet has 99.21% accuracy. MobileNet's feature extraction accuracy outperforms previous machine learning methods. This study included 3240 rural Bangladeshi fruit samples of eight varieties. With its high accuracy and web-based system, the proposed approach should help individuals and industry recognize local fruits (Rahman et al., 2023). This project uses deep learning to create a low-cost object identification system for blind individuals. TensorFlow object detection API and SSDLite MobileNetV2 trained on COCO are used for object detection. Final layer hyperparameters are optimized using particle swarm optimization (PSO). The MobileNetV2 model was 88.89% accurate. The model's detection accuracy, mean average precision, frame rate, confusion matrix, and ROC curve are tested on a desktop computer and a Raspberry Pi embedded system. This low-cost device should improve blind people's daily life (Islam et al., 2023). Prior studies have demonstrated noteworthy fruit and vegetable classification accuracy by utilizing the MobileNet model. Nevertheless, there exists the possibility of further enhancing these findings. The existing body of research exhibits deficiencies that indicate potential for improving accuracy through more advanced methodologies or by harnessing more extensive and diversified datasets. Ongoing research endeavors are focused on attaining optimal precision in the classification of fruits and vegetables, with the ultimate goal of yielding favorable outcomes in the agricultural and retail sectors and other relevant domains.

METHOD

Dataset

Downloaded fruit and vegetable datasets from Kaggle are valuable for visual object classification research, particularly in recognizing and differentiating fruit and vegetable varieties. This dataset consists of 3,958 images categorized into 36 distinct classes, each representing a different form of fruit or vegetable that humans commonly consume. The diversity of classes in this dataset is essential because it reflects actual variations in the real world. This dataset's source, Kaggle, is one of its most valuable characteristics. Kaggle is a well-known platform for exchanging scientific data and resources among researchers and practitioners. Kaggle provides access to high-quality datasets that have frequently undergone filtering and validation. In the context of this fruit and vegetable dataset, the presence of the dataset on Kaggle guarantees its quality and reliability. The data volume of 3,958 images provides substantial diversity, essential for training and evaluating classification models. In machine learning, datasets containing thousands of examples enhance a model's ability to generalize and identify patterns in more diverse data. This indicates that models trained with this large dataset are more likely to accurately classify various categories of fruits and vegetables in real-world scenarios.

The significance of this dataset is also reflected in its contribution to creating more accurate classification models. Image-based classification models, such as the one utilized in this study, rely significantly on representative training datasets to produce accurate results. Having such a large and diverse dataset enables researchers to develop models that can accurately recognize various fruit and vegetable types in the context of fruit

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and vegetable classification. Moreover, this dataset has numerous prospective applications beyond the realm of research. This dataset can aid in developing crop yield recognition and classification automation systems for the agricultural industry. This dataset can be utilized in e-commerce applications that enable consumers to efficiently search for and purchase fruit and vegetable products based on images. This is an example of how similar datasets can add value to various aspects of daily life. The fruits and vegetables dataset from Kaggle, containing 3,958 images in 36 classes, is a valuable resource with significant potential for research and practical applications. This dataset's diversity and quality provide a solid foundation for developing improved classification models, which can support multiple industries and enhance our understanding of the world of fruits and vegetables.

MobileNetV2

MobileNetV2 is one of the artificial neural network architectures designed specifically for visual object classification and image processing tasks in constrained computational environments, particularly mobile devices. This architecture is an evolution of the MobileNetV2 (Toğaçar et al., 2021) model, which was renowned for its ability to produce lightweight models without forsaking performance. MobileNetV2 has become one of the most popular options for developing resource-efficient and robust object classification models in the context of the Keras framework with TensorFlow as a backend. The MobileNetV2 architecture comprises two primary components that demonstrate its distinctive capabilities. Initially, there is the MobileNetV2 block, which employs depthwise separable convolution. Depthwise convolution divides spatial convolution operations into depthwise convolution (convolution in each input channel) and pointwise convolution (1x1 convolution). This significantly reduces the number of parameters and computations required in the network, which is particularly beneficial for devices with limited resources, such as mobile phones. Then, an insertion block (inverted residual block) is an integral part of MobileNetV2. This block employs multiple depthwise convolution layers with linear expansion, increasing the number of features per block. This is followed by pointwise convolution and the implementation of an exception mechanism (skip connection) to preserve and combine the necessary data. This method enables MobileNetV2 to comprehend more complex visual data representations without requiring extra computing resources.

MobileNetV2 utilizes TensorFlow as a backend for the Keras framework during the data training procedure. A dataset containing previously prepared images of fruits and vegetables is used as training data during the training stage. This dataset is then split into training and validation portions to prevent overfitting, which can negatively impact model performance when presented with new data. MobileNetV2 will undergo multiple training epochs. The network weights will be updated iteratively using an optimization algorithm, such as Stochastic Gradient Descent (SGD) or Adam, to decrease loss and improve accuracy. MobileNetV2 will learn various patterns and features that represent the different categories of fruits and vegetables in the dataset during the training process. Each image in the dataset is used to train the model, which is then evaluated for performance using validation data. By repeating this procedure over multiple epochs, the MobileNetV2 model's capacity to accurately classify various varieties of fruits and vegetables will be significantly enhanced. MobileNetV2 is an effective and robust artificial neural network architecture with TensorFlow support for visual object classification in the Keras framework. The training process utilizes a pre-prepared dataset to generate a model capable of accurately recognizing and differentiating various types of fruits and vegetables. It is a valuable resource for multiple applications, including automatic recognition and image processing on mobile devices.

RESULT

As the number of training epochs increases, the accuracy of the MobileNetV2 model changes, as demonstrated by your research findings. The following is a summary of these outcomes:

1. At epoch 5, the MobileNetV2 model's accuracy attained 0.9484. This demonstrates that after 5 epochs, the model is already quite adept at recognizing patterns in training data, although there is still room for development.
2. At epoch 10, the precision rose to 0.9835. This is a significant advance over previous results, indicating that the model's ability to classify data can be enhanced through additional training.
3. At epoch 15, precision increased further to 0.9869. After 15 training epochs, the MobileNetV2 model has attained high accuracy. The convergence of the training may have reached this point.

The trade-off between training duration and model performance should determine the optimal number of training epochs. If the model has already achieved adequate accuracy after a few epochs, continuing training for a more significant number of epochs may be inefficient. However, if the increase in precision is still substantial, continuing training may be a viable option for optimizing model performance. Accuracy results using MobileNetV2 can be seen in Figure 2.

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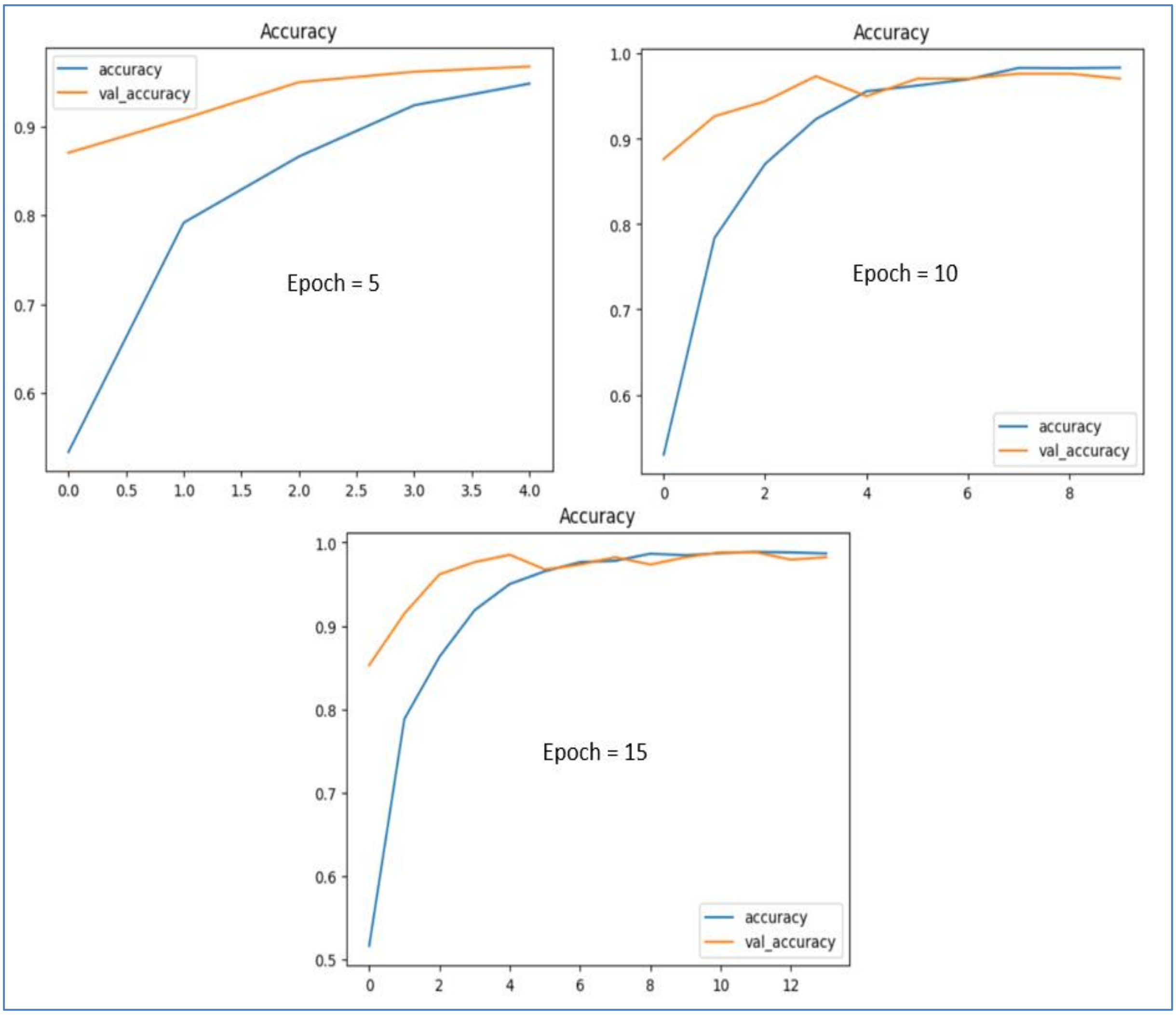

Fig. 2 Accuracy MobileNetV2
Source: Researcher Property

The research results demonstrate alterations in the MobileNetV2 model's loss value throughout the training procedure. The following is a summary of these outcomes:

1. At epoch 5, the MobileNetV2 model's loss value is 0.1769. This value indicates how well or inadequately the model evaluated the training data. The smaller the loss value, the more accurately the model predicts the training data.
2. The loss value decreased to 0.0542 at epoch 10. The decrease in loss value at epoch 10 indicates the model's ability to mitigate errors in the training data has improved significantly. This suggests that the model is approaching convergence.
3. At epoch 15, the loss value decreased further to 0.0459. This demonstrates that the MobileNetV2 model continues to improve its performance and is approaching a point where the loss reaches shallow values, indicating that the model is already quite adept at comprehending the training data.

The optimal number of epochs must also consider the trade-off between training time and model performance, as is the case with accuracy. Continuing training for a more significant number of epochs may only be practical if the loss value is already deficient and no longer displays a considerable decrease. Conversely, if the loss value continues to decline significantly, ongoing training can help improve model performance. The loss results using MobileNetV2 can be seen in Figure 3.

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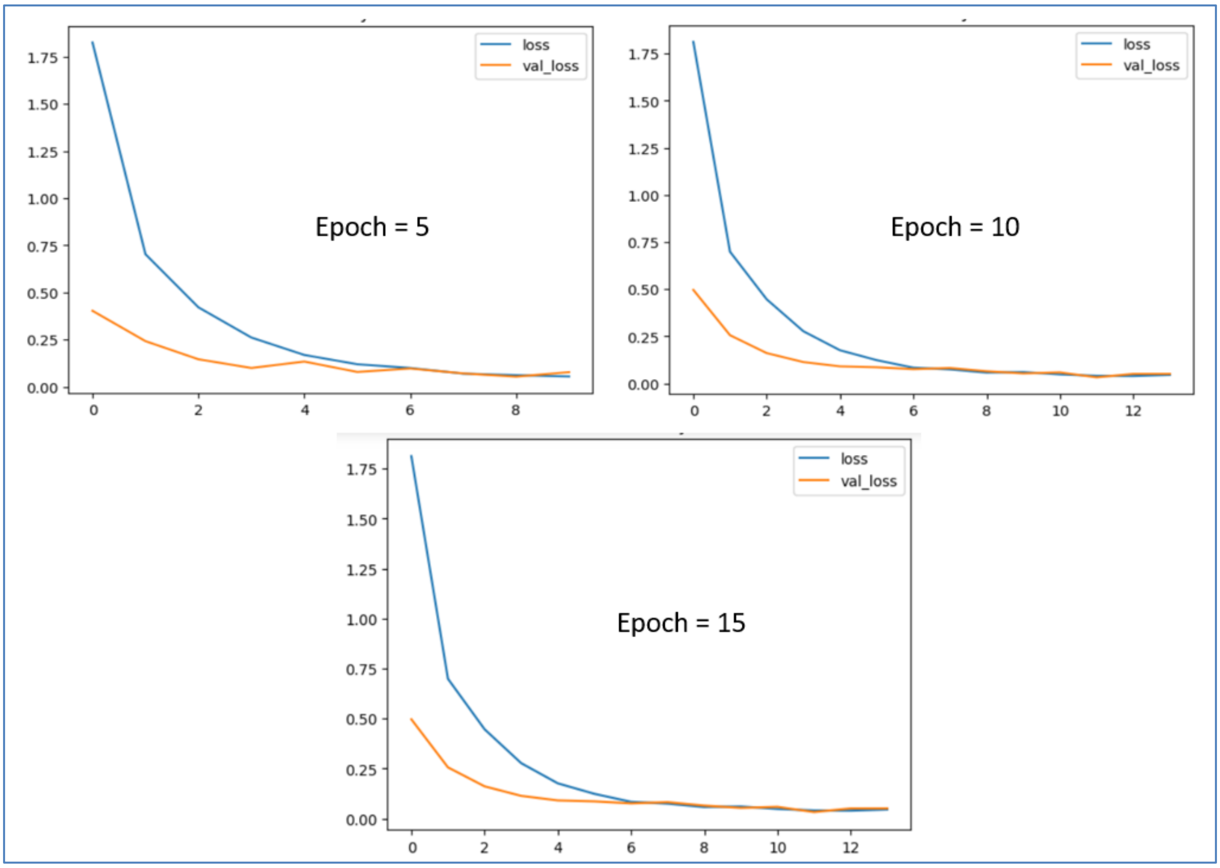

Fig. 3 Loss MobileNetV2
Source: Researcher Property

DISCUSSIONS

How can we optimize the architecture of artificial neural networks to classify fruits and vegetables with the utmost precision? (First Research Question).

A series of meticulous strategies are necessary to optimize artificial neural network architectures for the most accurate classification of fruits and vegetables. Choosing an appropriate architecture is a crucial initial step. Convolutional Neural Networks (CNNs), including variants such as MobileNetV2 or ResNet, are frequently an excellent choice for image classification tasks such as classifying fruits and vegetables. Next, proper hyperparameter optimization must be considered, including the learning rate, number of layers, and units per layer. Using pre-trained models, such as those trained on the ImageNet dataset, can accelerate training and enhance performance in computer vision. Data augmentation techniques are required to increase the training dataset's diversity, including rotation, shifting, and inverting—regularization techniques, such as dropout and l2 regularization, aid in reducing overfitting.

Additionally, ensure that the training dataset is sufficiently large and diverse, and evaluate the validation or test dataset using the appropriate metrics. Noteworthy is also the optimization of the model for inference on the target device, which includes compression or conversion of the model into an efficient format. Comparison with other models can aid in understanding the potential for further enhancements, and advanced tuning techniques, such as combining ensemble models or fine-tuning specific layers, can increase the classification precision of fruits and vegetables. This iterative process requires careful experimentation, but with a cautious approach, achieving maximum accuracy in this classification task is possible.

How does the use of epoch affect the accuracy of fruit and vegetable classification? (Second Research Question).

The number of epochs utilized in fruit and vegetable classification model training significantly affects the classification accuracy. The number of epochs indicates the number of times the entire training dataset is employed to train the model. Its impact on precision can be described as follows: Increasing the number of epochs early in training will typically enhance model performance. This is because the model has more chances to modify its

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weights to the training data and identify patterns that may not have been apparent in earlier epochs. Consequently, model performance can improve during this initial phase.

However, it should be emphasized that excessively increasing epochs can result in overfitting. Overfitting occurs when the model "memorizes" the training data rather than "understanding" the general patterns present in the dataset. This can result in poor efficacy on new data, such as validation or test data. Therefore, it is essential to discover a balance in the number of epochs employed. Monitoring model performance on validation datasets during training is a prevalent technique. If performance on a validation dataset begins to deteriorate after a certain number of epochs, this may indicate that the model has already started to overfit. Increasing the number of epochs will likely not improve the model's accuracy on previously unseen data.

In practice, the optimal number of epochs can vary depending on the dataset's complexity, the model's architecture, and the quantity of training data. A more significant number of epochs may be necessary for larger and more complex datasets to accomplish convergence, whereas a smaller number of epochs may suffice for more straightforward datasets. To obtain optimal accuracy in classifying fruits and vegetables, testing different numbers of epochs and monitoring model performance on validation datasets is essential. Using a methodical approach and careful experimentation, you can determine the optimal number of epochs to accomplish good model performance without overfitting.

CONCLUSION

The research "Entering a Comprehensive Exploration of Fruit and Vegetable Classification Systems" has contributed significantly to the understanding and development of fruit and vegetable classification systems. This study achieved an accuracy of 98.69% with a loss value of only 0.0459 at the 15th epoch through the MobileNetV2 algorithm and meticulous data processing. These results demonstrate that the model devised in this study can classify diverse types of fruits and vegetables with a high degree of precision. The success of this model has a variety of positive effects. Practical applications in the agricultural industry include automated and accurate crop monitoring, which can assist producers in optimizing crop yields. This model can be used in the retail sector to automatically classify fruit and vegetable products in supermarkets, facilitating more excellent stock management and product quality monitoring efficiency. In addition, the results of this research also emphasize the potential of using MobileNetV2 as a highly efficient algorithm in the context of image classification. MobileNetV2 provides a satisfactory balance between performance and model size, making it suitable for applications on resource-constrained devices, such as mobile devices. Nonetheless, this study demonstrates that constructing image classification systems still faces obstacles. Integrating more advanced artificial intelligence technologies, such as deep learning, remains an intriguing research topic.

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