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RESEARCH ARTICLE

Classifying enset based on their disease tolerance using deep learning

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Abstract

Even though agriculture remains the main source of Ethiopia's population economy, not identifying enset based on their disease tolerance level is an obstacle for the production of enset.This paper's main objective is to automatically identify the disease resistance levels of enset plants through digital image. The researcher followed the design science research method to achieve the objective listed above. Besides, the researcher has attempted to get valuable information about the type and the nature of these classes from the domain expert through interviews, document analysis, and observation from the fields. The total number of images used for experimentation purposes was 3000. The Contaharmonic filtering technique was implemented to remove noise due to its highest entropy recorded. A deep learning-based approach with training from scratch and transfer learning convolutional neural network methods were applied. Based on this, the researcher made experimentation for transfer learning by using two different pre-trained models, namely VGG-19 and VGG-16. Finally, the developed classifier model's performance was assessed using accuracy, precision, recall, and the F1 score. According to the interpretation of the results, the proposed model's training from scratch method achieves 92.6%. On the other way, the accuracy obtained with the transfer learning method, VGG-16 achieves 98.5%, and VGG-19 achieves 93.9%. Hence, transfer learning, specifically the VGG-16 model revealed an effective and robust performance for classifying enset based on their disease tolerance level based on the researcher's number of images.

Keywords: Deep learning, VGG-19, VGG-16, Enset, CNN.

Introduction

Agriculture is the broadest term, encompassing many ways in which crop plants and domestic animals sustain the global human population by providing food and other products(Harris and Fuller, 2014). The English word agriculture is derived from the Latin ager (field) and colo (cultivate), which together form the Latin agriculture: Field or land tillage (Signa, 2015; Abbas, 2016). But the word has come to subsume a very wide spectrum of activities that are integral to agriculture and have their descriptive terms, such as cultivation, domestication, horticulture, arboriculture, and vegeculture, as well as forms of livestock management such as mixed crop-livestock farming, pastoralism, and transhumance. Also, agriculture is frequently qualified by words such as incipient, proto, shifting, extensive, and intensive, the precise meaning of which is not self-evident (Demeke and Ferede, 2014). Agriculture is one of the most important sources of income for the national economy, and it plays a critical role in feeding the world's population. Agricultural researchers and scientists are working hard to maximize yield without environmental impact (Signa, 2015).

Ethiopia's economy is primarily based on agriculture which is also the main source of income for nearly 85% of Ethiopians (Demeke and Ferede, 2014). Ethiopia is endowed with abundant agricultural resources and has diverse ecological zones. The government of Ethiopia has identified key priority intervention areas to increase the productivity of smallholder farms and expand large-scale commercial farms. Under the new administration, the government has renewed emphasis on developing the agriculture sector and ensuring food security. Among the top priorities identified by the government include small and large-scale irrigation development, financing agricultural inputs, increasing the productivity of crops and livestock, improving agricultural

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production methods using mechanization, post-harvest loss reduction, developing a research-based food security system, and natural resource management (Wolde, 2017).

Besides these, as part of the homegrown economic reform agenda, the government is looking to the agro-processing sector as one of the engines to spur future economic growth (Demeke and Ferede, 2014). Concerning increasing productivity, the government has made several interventions to support the development of the agriculture sector.

These activities have contributed to higher yields and increased productivity of both crops and livestock. At the same time, to accelerate the country's agricultural development, the government established the Agricultural Transformation Agency (ATA) to address systemic bottlenecks in the agriculture sector by supporting and enhancing the capability of the Ministry of Agriculture (MOA) and other public, private, and non-governmental implementing partners (Demeke and Ferede, 2014).

Enset (ventricosum) is a traditional multi-purpose crop primarily used as a staple/co-staple food for over 20 million Ethiopians (Hiwot, 2015). It provides food (amicho, bulla, and Kocho), animal food, cultural materials, and medicine and helps to conserve soil water (Gebre, 2019). The most serious biological problem caused by bacteria, fungi, viruses, and nematodes is disease. The most significant constraint to Enset production is the bacterial wilt of the Enset. There is no specific preventive or curative action for these diseases. For these reasons, farmers and different agriculture sectors claimed that the classifying ensets based on their level of tolerance for disease for cultivation as one of the ways to prevent disease (Tsehaye and Kebebew, 2006).

Enset (*Ensete ventricosum* (Welw.) Cheesman) is the only species of the genus *Ensete* that is Cultivated and consumed as a crop (Yemataw *et al.*, 2017). It belongs to the family Musaceae and is a giant herbaceous monocotyledonous plant consisting of an adventitious root system and underground stem structure known as a corm, a pseudo stem that is formed from leaf sheaths that extend from the base of the plant, leaves, and inflorescence (Yemataw *et al.*, 2017).

Ethiopia is both the center of origin and the center of diversity for enset. Enset cultivation has been largely confined to Ethiopia and genetic improvement of this crop is entirely dependent upon the characterization and exploitation of Ethiopian germplasm resources (Yemataw *et al.*, 2017).

The main food product, known as Kocho which is well known around the researcher's site, is made by fermentation, a combination of scraped pulp from the pseudostem, pulverized corm, and an inflorescence stalk (Mojo, 2017). The corm can be harvested at almost any stage of the crop and cooked and consumed in the same way as other root and tuber crops, relieving hunger during periods of critical food shortages. *Kocho* can be stored for a long time without spoiling (Gebre, 2019)(Mojo, 2017).

Depending on the landraces cultivated in the home gardens. Pseudostem color, midrib color, plant size, as well as leaf color were the most commonly mentioned identification descriptors. A researcher used the midrib color and leaf color of an enset from these descriptors to classify the ensets based on their disease resistance level (Gebre, 2019).

No means of technology is applied to identify these diseases resistance level for enset. Even though using technologies in agriculture is very important for more productive and sustainable production (Mojo, 2017; Gebre, 2019)(Aki, Gullu and Ucar, 2016).

Through the use of computational models to perform image processing on digital images is referred to as digital image processing. It is a method to perform some operations on an image, get an enhanced image, or extract useful information from it (Aydogdu, Celik and Demirci, 2017). It is a kind of noise removal in which the image is created and the output can be an image or properties present in an image(DEVI, 2020). Nowadays, image processing is among rapidly growing technologies. It also forms a core research area within engineering and computer science disciplines (Gonzalez, Woods and Prentice Hall, 2008).

Deep learning is a part of machine learning that uses several layers containing non-linear processing units, and each layer uses the previous layer's output as input. A convolutional neural network (ConvNet/CNN) is a deep learning algorithm that can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image, and be able to differentiate one from the other (Al-Daour, Al-Shawwa and Abu-Naser, 2019; Amlekar and Gaikwad, 2019).

The objectives of the study

General objective

The general objective is to design and develop a classification model on Enset (ventricosum) plants using deep learning based on their disease resistance level.

Specific objectives

The aforementioned specific objectives are ready in this study to achieve the overall goal.

- To review the literature on previous studies conducted on the classification of different plants by using image processing techniques.
- To collect and prepare enset leaf images for deep learning.
- To identify which training splitting methods are most appropriate for classifying disease tolerance levels with a limited dataset
- To identify which technique of CNN is good for the classification of enset based on their disease tolerance level.
- To identify to what extent the deep learning algorithm classifies the level of disease tolerance level of Enset.

Material and Methods

Data collection

A digital camera with a high-quality megapixel with high resolution was used to capture the image from the farm field that the image can exist. The researcher collected data from Enset farm as the primary input. Images were collected from three different woredas (Chena, Shishinda, and Gimbo) from the Kaffa zone in SNNPR, Ethiopia. The researchers collected all data from the field. Depending on this we collected 1500, 800, 700 from Chena, Shishinda, and Gimbo woreda, respectively.

Depending on the number started above from the Chena site the researchers collected 500 images for low class, 400 for the medium class, and 600 for high class. From the Shishinda site 200 images for low class, 400 for the medium class, and 200 for high class. And from the Gimbo site, the researchers collected 300 for the low class, 200 for the medium class, and 200 for the high class.

Methods

This research followed the design science research paradigm for the research methodology because of the nature of this research and the steps the researcher followed to conduct this research are more suitable for this research methodology. It has correctly defined steps that are going to ensure a good result for data preparation, image preprocessing, model building, and evaluation (Hevner and Chatterjee, 2010). These activities listed above are generalized into problem identification and motivation, objective definition, designing and developing artifacts, demonstration of the artifact for end-users, evaluation, and communication (Peffers *et al.*, 2007; Offermann *et al.*, 2009; Alturki, Gable and Bandara, 2013).

This research was implemented using Python programming languages due to its being open-source, easy to code, and most popular for implementing image processing research and like. Python libraries were used, such as Open CV Python library for a binding designed to solve a computer vision problem, and NumPy python package for image manipulation. It is extremely fast, allowing our algorithms to run with computational complexity efficiency, which is one of the desired characteristics of the proposed work. Open CV Python makes use of NumPy, a highly optimized library for numerical operations that include N-dimensional array objects, and Scikit-learn, a free Python machine learning library. This work is experimented with by using google Collaboratory due to the less performance of the researcher's computing device. The researcher used a convolutional neural network for classification purposes to achieve the desired goal due to its advantage compared to its predecessors in automatically detecting the important features without any human supervision (Al-Daour, Al-Shawwa, and Abu-Naser, 2019).

Results

The results of the study are shown in Figures 1-4.

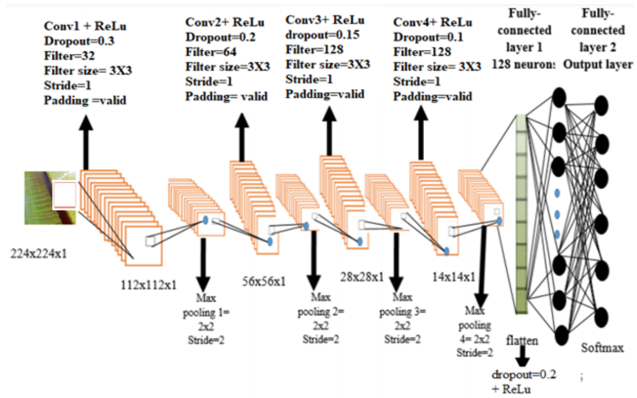

Figure 1: proposed training from the scratch model

```
              precision    recall  f1-score   support

           0       1.00      0.81      0.89       325
           1       0.90      0.99      0.94       298
           2       0.87      0.98      0.92       277

    accuracy                           0.92       900
   macro avg       0.92      0.92      0.92       900
weighted avg       0.93      0.92      0.92       900

[[262  27  36]
 [  0 294   4]
 [  1   4 272]]
```

Figure 2: The confusion matrix for training from the scratch (70:30)

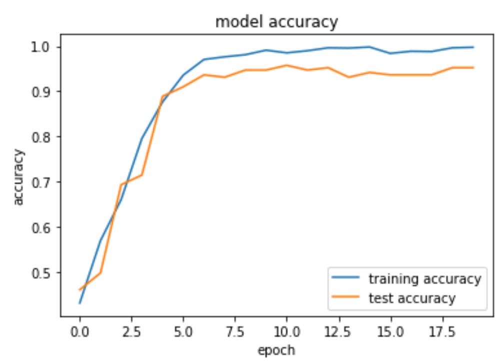

Figure 3: Graph of training and test accuracy for 70:30 splitting (training from the scratch)

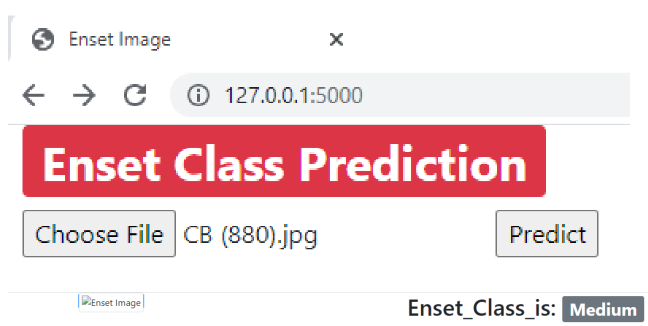

Figure 4: Sample model testing by the developed user interface

Discussion

In agriculture activity identifying the different crops based on their disease tolerance level is very essential for more productivity. Therefore, classifying enset based on their disease resistance level is very essential to match the weather and the enset crops for more productivity. Ethiopia, especially South-Western Ethiopia has more suitable land for the production of enset and benefited from that. However, it is most popular in this area because production is unavailable in other parts of Ethiopia. That is why the classification of enset based on their disease tolerance level system is very essential.

The primary goal of this study was to create an automatic enset disease tolerance level classifier model with CNN using a deep learning-based approach. Therefore, this study has made an effort to detect and classify the enset disease tolerance level automatically using a convolutional neural network. Besides, the researcher has tried to develop a prototype graphical user interface to effectively utilize the developed classifier model.

This study used design science research methodology, which is relevant for problem identification, opportunities in the business, and applicable knowledge that allows us to create an artifact from rigor.

In this work, the researcher collected 1000 images for high disease tolerance, 1000 for medium and 1000 for low disease tolerance. And all the images are collected from the field and the Techno smartphone captures them with a camera quality of 13MP. The researcher researched by using 3000 images in all three classes.

The researcher used the Contaharmonic noise removal technique by measuring the entropy of each noise removal technique experimented by the researcher without losing the image quality of naturalness of the original image.

This research is conducted by a deep learning-based approach. Specifically, training from scratch and transfer learning convolutional neural network methods were used to build a model that can classify the enset based on their disease tolerance level.

Depending on this, the researcher has developed a convolutional neural network using training from the scratch method and transfer learning techniques (VGG-19 and VGG-16) by applying image augmentation techniques to minimize model overfitting.

As a result, model 80 by 20% and 70 by 30% split test options were used to develop a classification and a confusion matrix to visualize model performance. The evaluation of the best-performed models was compared based on accuracy, recall, precision, and F1 score. Therefore, the developed model performed an accuracy of 92.6%. Besides a graphical user interface was designed for this model, and this graphical interface was developed using Flask. Hence, transfer learning methods are preferable and the most recommended techniques while training the convolutional neural network with a small dataset. Finally, this study recommended agricultural experts use this system because the system is cost-effective and less time-consuming for increasing agricultural productivity.

Conclusion and Recommendation

This research was conducted to identify enset based on their disease tolerance level on both training from scratch and pre-trained model can be considered as a contribution of the study. The dataset which the researcher collects is submitted to the agricultural research center of the Kaffa zone.

The developed convolutional neural network classifier model is trained by giving an augmented input image to the convolutional neural network to automatically extract valuable features from the input. The developed model performed an accuracy of 92.6%. In addition to this, a graphical user interface was designed for this model, and the development of this graphical interface was by using the flask platform. Finally, the researchers recommended the following points for the next research.

- Due to treat for class imbalance, the researcher used limited enset landrace because the number of landraces for each class is not equal in number. For example, the medium disease tolerance class label has the least number of enset landraces. So, one can develop a model by increasing a landrace by handling class imbalance using different mechanisms.
- Here, the experimentation was conducted by using training from scratch and transfer learning (VGG-19 and VGG-16). So, one can improve the performance by changing different hyper-parameter values in case of training from scratch and making different transfer learning experiments in the case of transfer learning mechanism.

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