Crop management using predictive data analytics and leaf venation networks

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Introduction

Agricultural production in sub-Saharan Africa is hindered many factors including crop pests and diseases. In addition to this, the ability to predict crop yield is a challenge that needs to be overcome especially in countries like Malawi where most predictions are done by using unreliable survey data and where precise information about meteorological conditions, soil properties and land cover are not available. This study seeks to use predictive data analytics and leaf venation networks for crop management by developing machine learning models for plant species identification, crop disease detection, and crop yield prediction.

Objectives

The aim of this research is to employ predictive data analytics techniques for crop management by focusing on the following specific objectives:

- To develop an optimal non-invasive leaf venation network (LVN) extraction method;
- To develop crop yield prediction models using machine learning (ML) techniques trained on leaf vein density (LVD), normalised difference vegetation index (NDVI) and enhanced vegetation index (EVI), and climatic data;
- To determine the best ML approach for plant species recognition among classical ML methods, deep learning and ensemble approaches;
- To determine how plant diseases affect LVNs using self-organising maps (SOMs) and rule induction;
- To use LVNs for the development of ML models for disease detection.

Data Collection

Leaf image data was collected from crop fields in Malawi using a mobile phone camera. Three sites were chosen based on availability of crop and a custom dataset was created.

Figure 1. Rape Leaves (*Brassica napus L.*)

Figure 2. Potato Leaves (*Solanum Tubersolum L.*)

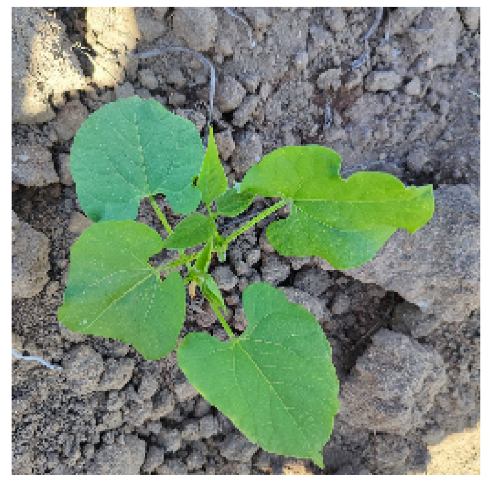

Figure 3. Beans Leaf (*Phaseolus vulgaris*)

Figure 4. Peas Leaves (*Pisum sativum*)

Methods

Figure 5 shows the main approach that will be taken in this piece of research.

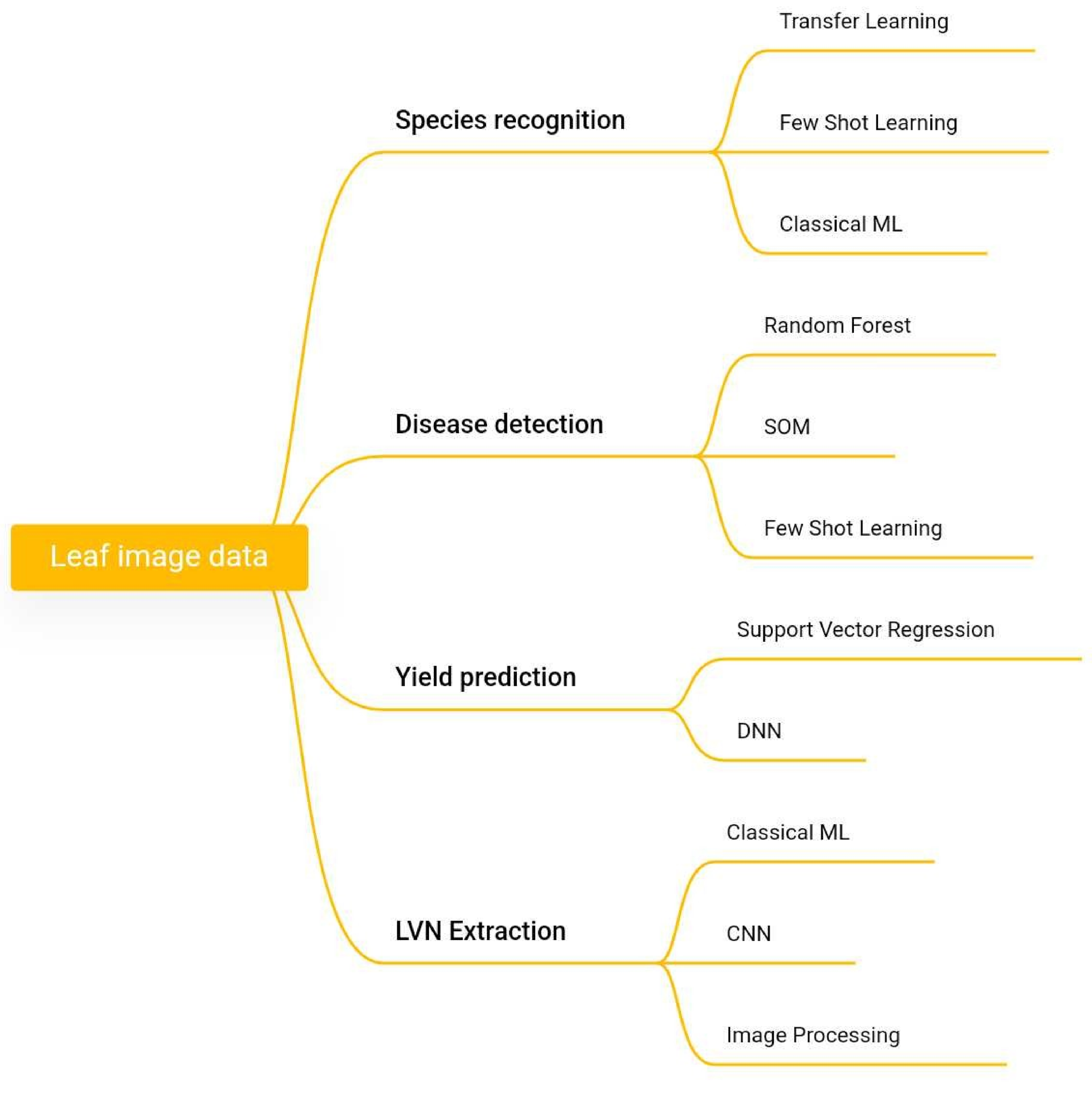

Figure 5. General Methodology

LVN Extraction

The topology of LVNs differs between cultivars and across species. We will exploit this fact to develop crop species recognition models.

Figure 6. LVN Extraction Pipeline

Results

We used transfer learning to develop a deep learning model for crop classification. Our dataset contains leaf images of peas, beans, varities of potatoes and rape.

Tables 1 and 2 show results of using transfer learning to classify images from our dataset. We used two approaches: in the first approach, we used a pretrained network as a feature extractor. That is we, froze the feature extractor part of the network, added our own classifier, and then retrained the network on our new small dataset. In our second approach, we fine-tuned the network by freezing a few of the network layers that are used for feature extraction, and jointly trained both the non-frozen layers and the newly added classifier layers of the pretrained model, see Figure 7.

Classifier	Accuracy
RF	78%
XGBOOST	83%

Table 1. VGG16 pretrained network as a feature extractor

Details	Accuracy
optimizer = adam learning rate =0.0001 loss = categorical_crossentropy classifier = softmax with 6 units	99.4%

Table 2. VGG16 fine-tuned pretrained network

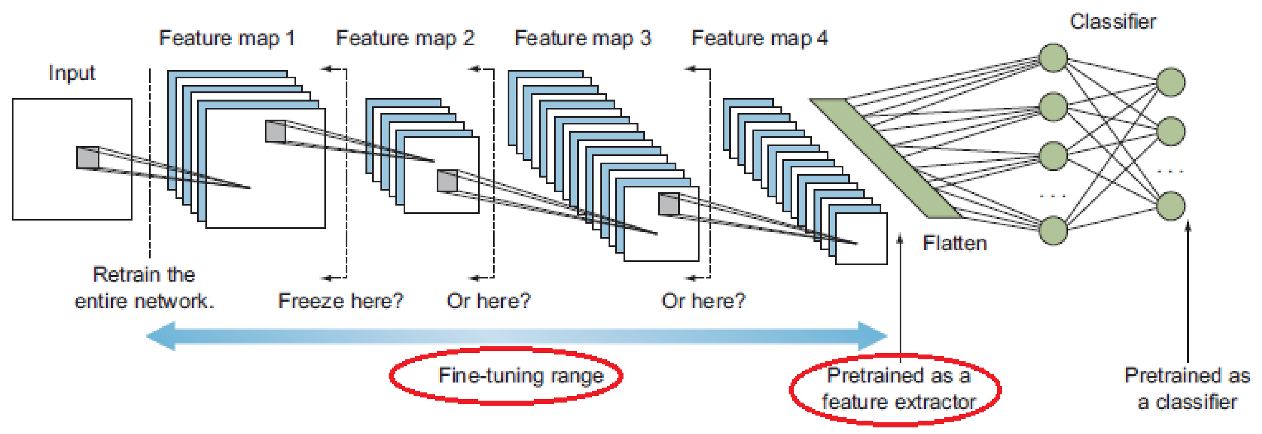

Figure 7. Approaches used in transfer learning [0]

Next Steps

- Image annotation for semantic segmentation.
- Further model building.
  - Try other ML models (e.g. LightGBM, SVM) as classifiers in the pretrained network
  - Try other pretrained netowrks for transfer learning e.g. inceptionv3 and RESNET50.
  - Apply feature engineering to enhance feature extraction in the pretrained network.

References

Chicco D. (2021) Siamese Neural Networks: An Overview. In: Cartwright H. (eds) Artificial Neural Networks. Methods in Molecular Biology, vol 2190. Humana, New York, NY.

Elgendy, M., (2020). *Deep learning for vision systems*, Manning Publications, New York.

Grinblat, G.L. Uzal, L.C., Larese, M.G., Granitto, P.M, (2016). Deep learning for plant identification using vein morphological patterns. *Computers and Electronics in Agriculture*, 127, 418-424.