Early identification of *Tuta absoluta* in tomato plants using deep learning

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DSA Research Seminar

November 12, 2020

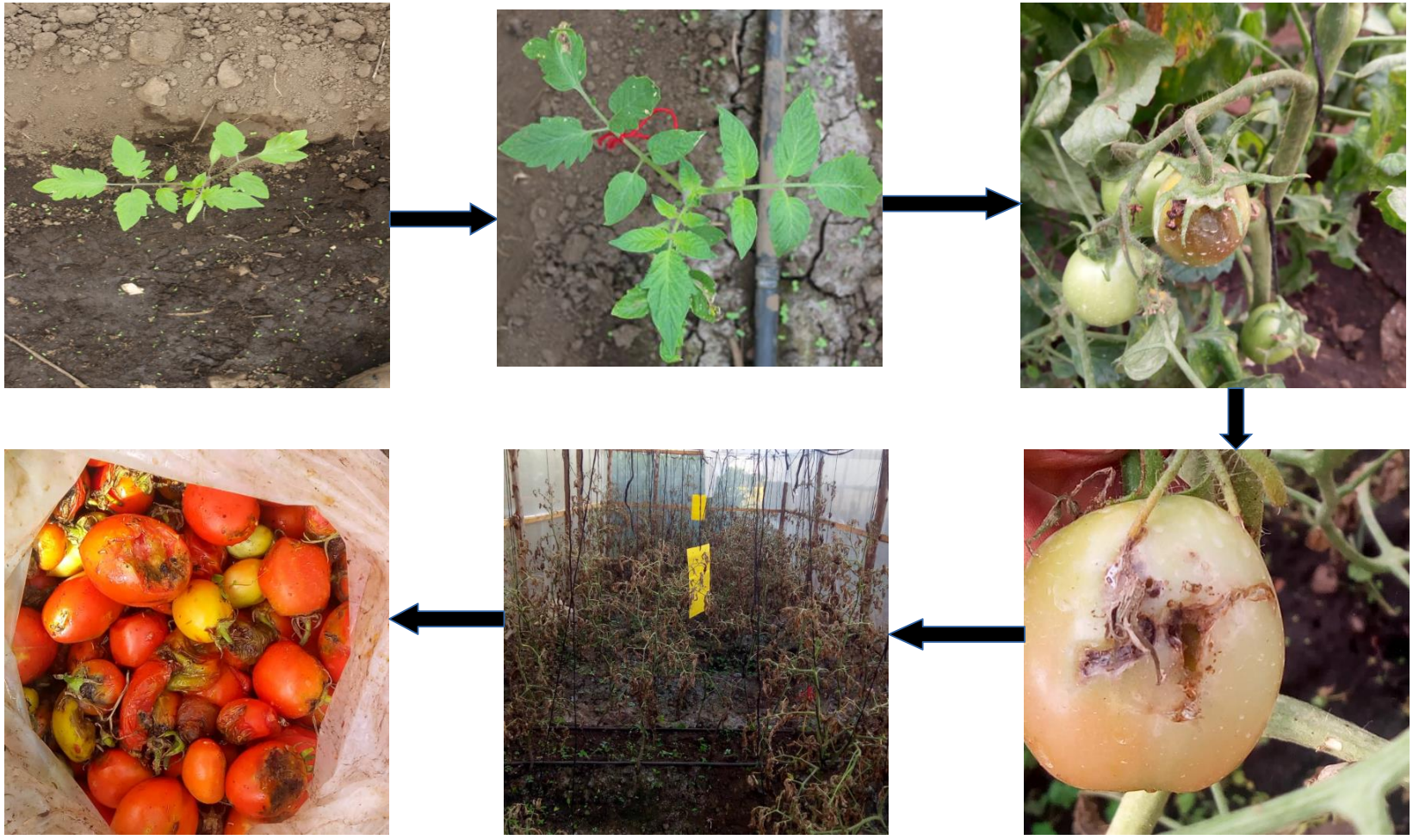
Introduction

- Tomato *(Lycopersicon esculentum)* is a nutrition-rich and an edible plant that is widely grown throughout the world (P. Schreinemachers et al., 2018).
- Approximately 160 million tons are produced each year globally, in Tanzania about 247,135 tons harvested in 2016 (Mutayoba et al., 2017).
- Source of income to small scale farmers in Sub-Sahara African countries.
- Given the economic importance of tomato, we should consider the factors affecting its production and find more appropriate technological solutions to maximize its productivity.

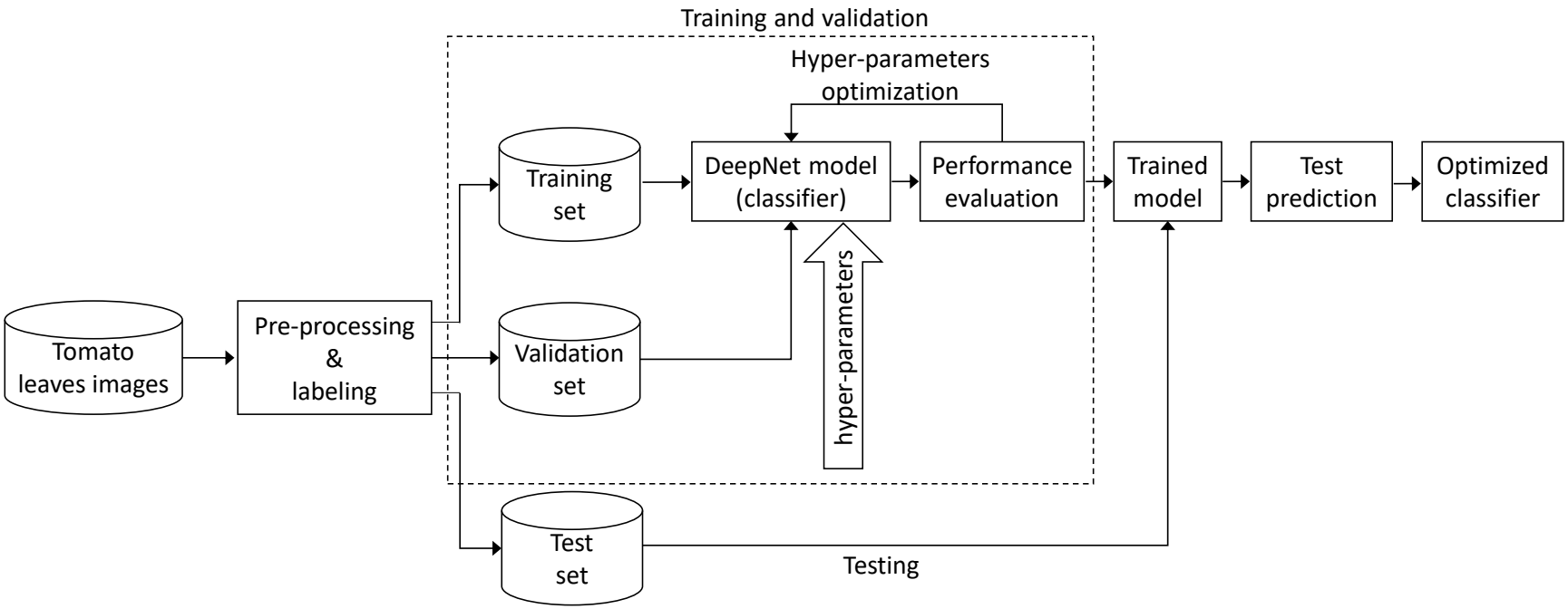
Problem Statement

- Tomato productivity is threatened by invasive pest called leafminer *Tuta absoluta* famously known as *"Kantangaze"* in Tanzania, being causing great loss (Zekeya et al., 2017).
- Despite existence of various ways of controlling the pest, early identification of the pest remains an open-ended research question.
- In Tanzania, for instance agriculture depend on local extension officers as key facilitator (Maginga et al., 2018)
- There is a need to integrate sophisticated technologies, including those based on deep learning, into agriculture to identify pest and to maximize productivity.

Tuta absoluta farm situation



Research Framework



Methodology

- Dataset acquisition
  - Field trial setup
  - Images capturing
  - Preprocessing
- Model development
  - Convolutional Neural Network
- Model evaluation
  - Accuracy and Loss
  - Confusion matrix
  - Evaluation metrics

Dataset acquisition

- Field trial in a net–house at Usariver, Arusha
- Planting tomatoes and inoculating with *Tuta absoluta* larva
- Image capturing using Canon EOS Kiss X7 camera with a resolution of 5184 X 3456 pixels
- We collected a total of 2145 images (330 being infected with *Tuta absoluta*)

Dataset acquisition

- Sample leaf images collected from the field
- (a) is the health leaf before inoculation and the red boxes shows the infected leaf, in (b), (c) ,(d) and (e) is the infected leaf on the 2^{nd} , 4^{th} , 6^{th}, and 8^{th} days respectively, after inoculation with the *Tuta absoluta*.

Image Pre-processing

- Manipulation of raw image data before being passed into deep learning algorithm to enhance data quality.
- It involved:
  - Labelling: into Health and Non–health classes
  - Resizing: Using Keras *resize* function
  - Augmentation: Several transformation to increase dataset and prevent overfitting.
- Handling data imbalance

Handling data imbalance

- Images equivalent to 10% of non- health images were held out as test set
- The remaining images were subdivided into 6 clusters
- Each cluster was trained as a separate dataset
- Overall accuracy was calculated as an average over six runs

Table 1: Dataset division

Class	Dataset	Training set	Validation set	Testing set
H	75:25	223 X 6	74	33
	80:20	237 X 6	60	33
	85:15	252 X 6	45	33
NH	75:25	223	74	33
	8:20	237	60	33
	85:15	252	45	33

Model Development

- Convolutional Neural Network was used to train our models
- We used transfer learning of three pretrained CNN architectures:
  - VGG16
  - VGG19
  - ResNet50
- The experiments were conducted on a desktop computer, pre-installed with Ubuntu 18.04 and equipped with one Intel Core i9-9900 3.6 GHz CPU (16 GB RAM) accelerated by one GeForce RTX 2080Ti GPU (12 GB memory).
- Keras deep learning library with Tensorflow backend was used.

Model Development

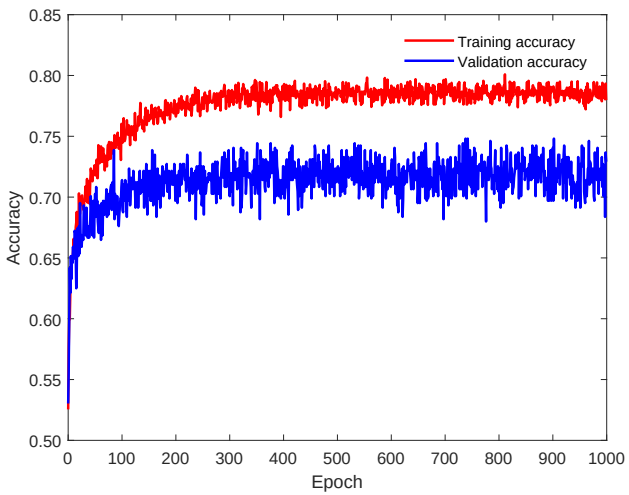
- Model hyper-parameters

Table 2: Model hyper-parameters

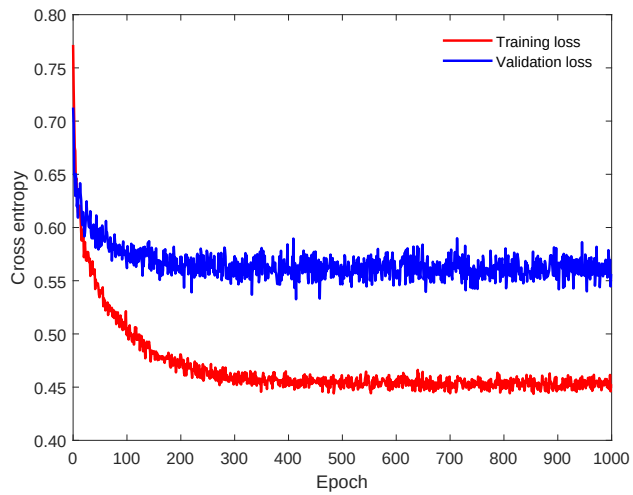
Parameter	**Value**
Epoch	1000
Batch size	8
Optimizer	SGD
Learning rate	1e-5
Dropout	0.5
Momentum	0.9
Early stopping	50 epochs

Model Evaluation

- Accuracy and loss
  - Model was evaluated during training at the end of each epoch by using validation data
  - The graphs below shows training and validation accuracies (a) and losses(b)



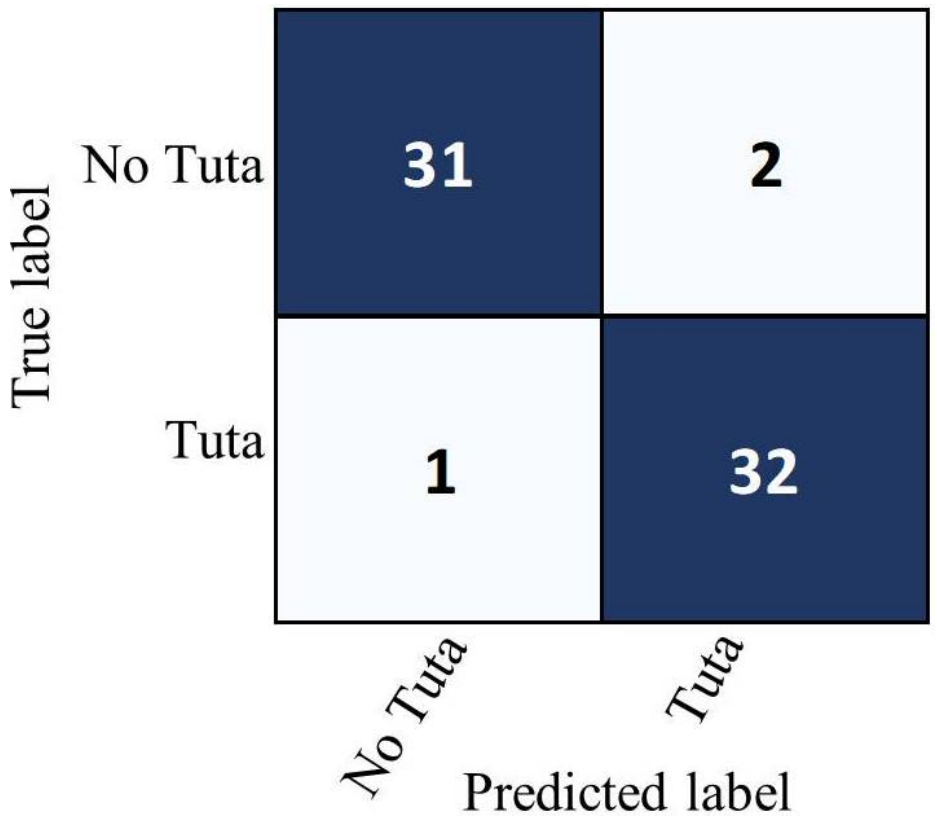
(a)



(b)

Model Evaluation

- Confusion matrix
  - The testing images indicated in the table above were used to evaluate ability of our model to predict new data.
  - Prediction results were visualized in the confusion matrix



Model Evaluation

- F1–score, precision, recall and accuracy were used as our evaluation metrics
- The best performance accuracy was attained by VGG16 on 85:15 dataset, was 91.9%

Table 3: For every Dataset, F1–score {mean precision, mean recall, overall accuracy}

Dataset	VGG16	ResNet50	VGG19
75:25	$0.901_{\{0.909,\ 0.901,\ 0.901\}}$	$0.852_{\{0.856,\ 0.853,\ 0.853\}}$	$0.839_{\{0.852,\ 0.841,\ 0.841\}}$
80:20	$0.906_{\{0.915,\ 0.915,\ 0.905\}}$	$0.854_{\{0.867,0.856,\ 0.856\}}$	$0.831_{\{0.853,\ 0.841,\ 0.836\}}$
85:15	$0.919_{\{0.922,\ 0.919,\ 0.919\}}$	$0.868_{\{0.871,\ 0.868,0.868\ \}}$	$0.831_{\{0.851,\ 0.833,\ 0.833\}}$

Research Contribution

- Model to be used by farmers and extension officers in detecting invasion of *Tuta absoluta* at early stage of tomato plants growth
- An open source dataset to facilitate further research in *Tuta absoluta* identification from diseased tomato plants(to be published)
- A ppaper titled Early identification of *Tuta absoluta* in tomato plants using deep learning (https://doi.org/10.1016/j.sciaf.2020.e00590)

Limitations of the study

- Deep learning is data hungry, that affects model performance accuracy.
- Running deep learning models requires high computational power resources which are scarce in our working environment.

Achievements

- Presentations attended
  - Poster presented in the Deep Learning Indaba 2019 conference, at Kenyatta University.
  - Poster presented in Black in AI workshop in the NeurIPS Conference 2019, Vancouver Canada.
- Awards
  - The won an award from Ai4D to facilitate collection of more data

Thank you!