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Weeds Classification using Convolutional Neural Network Architectures

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Abstract

Agriculture is an important sector for both human survival and economic growth. It has to be managed efficiently. This can be done by the use of technology in order to minimize human effort. It can be managed efficiently by following crop management tasks. One such crop management task is the identification and removal of weeds. Weeds are considered to be plants which are not required to be grown with the agricultural crops, because the weeds also utilize the water and nutrients like the agricultural crop and cause impact on the growth of agricultural crops. In order to identify weeds, deep learning technology can be used. The proposed system helps to classify weeds using Convolutional Neural Networks. This system employs models like, ResNet50, MobileNetV2 and InceptionV3, which are used for better classification. The system is evaluated based on these models, and all the three models have resulted in better accuracy.

Keywords: Machine Learning, CNN, Weeds, Deep Learning Residual Network, MobileNetV2, InceptionV3

1. Introduction

Machine learning (ML) is said to be the field of Artificial Intelligence (AI). The term machine learning was coined by Arthur Samuel. Machine learning enhances the capability of a machine by making it to learn from data automatically, and to enhance its performance from

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experiences that are gained from the past, and to predict things without the need of being explicitly programmed.

Weed is a plant which grows in a place where it is not required. Weeds usually compete with agricultural crop plants for water, light, and nutrients. In agriculture, the control of growth of weeds is a very important task that has to be performed in order to maintain high levels of crop production. The solution is to develop a method to classify weeds using Machine Learning and Deep Learning techniques. This solution would lead to an efficient management of crops.

The features of machine learning are as follows:

Supervised Learning: The model is provided with data which contains both input and output fields, that is, the dataset is labeled. This method finds the pattern and connection between the input and the output. It is of two types: Classification and Regression.

Classification: This method provides a solution for solving classification problems. The dataset contains the output which contains categorical values. Here, the algorithm predicts the categories present in the dataset. There are two types of classification: Binary Classification and Multiclass Classification.

Binary Classification: It refers to the method that involves classifying two types of classes.

Multiclass Classification: It refers to the method that involves classifying more than two types of classes.

Unsupervised Learning: The model is provided with an unlabeled dataset. The algorithm groups the dataset based upon the differences, patterns and similarities.

Reinforcement Learning: In this method, an intelligent agent is said to interact with the environment and it learns to work within that environment. Reinforcement learning is about making decisions sequentially i.e., the output is dependent on the status of the current input and the next input is dependent on the state of output of the previous input. Here, an unlabeled dataset is used.

Deep Learning (DL) is a technique of machine learning. It is a neural network. The DL technique consists of many types which include Convolutional Neural Network (CNN), Deep Belief Network, Deep Reinforcement Network, Deep Neural Network, Recurrent Neural

Network, etc. The deep learning model has efficient accuracies. It requires no explicit programming.

2. Literature Review

Paper [1] explained the concepts of machine learning and deep learning and their applications. ML is said to be the subset of Artificial Intelligence. It is related to different sectors such as data mining, statistics, and optimization techniques. This research compared the various methodologies that come under the concepts of ML and DL.It described the concepts of data science. Machine learning is required for any kind of analysis that has to be performed. Deep learning is said to be one of the concepts of machine learning. The basic architecture of Deep learning was explained.

Paper [2] surveyed various ML algorithms. It gives the computer the capability such that it can learn from the data belonging to the past and experience without being explicitly programmed. It states that if the dataset available is small in size and labeled, then supervised algorithms can be used. If the dataset is unlabeled and large, then unsupervised learning can be used. If the dataset is huge, then deep learning techniques can be applied on it.

Paper [3] suggested that supervised learning method is used for segmenting plant from background in its images and it is compared with the threshold methods. An approach in order to produce accurate labels was developed. Three thresholding methods that includes binary thresholding, mean adaptive thresholding and otsu thresholding are used for segmentation. Labeled training data is obtained by cropping the background and using K-means clustering. Various methods like Linear and Quadratic discriminant analysis, Random Forest, Neural network, and Support Vector machine have been applied on the dataset. It was found that neural networks perform better in segmentation and handling misclassifications. It was demonstrated that supervised learning methods and neural networks can perform better than thresholding methods with proper selection of training data.

Paper [4] provided the comparison of supervised identification of plants by using various methodologies. The techniques such as Decision tree, Naive Bayes, K-nearest neighbor, and neural network were used. The leaves dataset contains hundred species of leaves with 1600 samples. The work studied the representation of leaves in identifying the plant. Four

approaches were used. It states that neural network proved to be the better approach than other approaches. K-nearest neighbor and Naive Bayes were also efficient.

Paper [5] presented the model to classify weed and crop species using convolution neural networks. The training and testing were made on 10,413 images. These are images of 22 weed and crop species that are present in earlier stages of growth. The system used six different data sets, which vary with respect to lighting, resolution, and soil type.

Paper [6] developed a model for classifying weeds. The proposed model classifies 12 species of weeds using convolution neural networks. The dataset used was ImageNet database. Transfer learning technique was used to classify weeds from crops. This model can be further developed to classify some other variety of species across other countries. In [7], the classification approach for plant seedlings CNN was engaged for the dataset containing 5,000 images and 12 different species that were in their developing phases.

Paper [8] proposed a plant classification method based on Deep neural network for biodiversity protection and conservation. Among the various machine learning algorithms, deep neural network was applied on different plant datasets. The usage of results of multiple applications of DNN was implied by transfer learning based on machine learning. The model uses four datasets which includes Flavia dataset, Swedish leaf dataset, Plant village dataset, and UCI leaf dataset. It was demonstrated that transfer learning provided a better model for automatically identifying plants and improved low performing classification models of plant. The future work stated would use the same technique for the detection of plant disease and detection of weeds.

The aim of the work [9] was to build a system which automatically controls weed. The system consists of motors, camera and raspberry pie.

An automated image classification system was designed to distinguish weed from crop. CNN was used to classify the image of the object. Here Deep Learning model has been used to analyze the features from the image. The dataset containing 224 sample images of crop and weed seedlings has been used for research. The system classified the input into two categories as crop and weed.

Paper [10] surveyed the method of classification and detection of weed using different kinds of techniques in image processing, Machine learning, and Deep learning. The method

involves Support Vector Machines (SVM), convolution neural networks, pre trained CNN models like VGG16, Resnet, Lattice weeds localization, and Faster RCNN. It states that Transfer learning performs better for classification, and Yolo-v3 are best for object detection. In the future, Segmentation can be applied along with these method for classifying weeds with better accuracy.

Paper [11] suggested a computer-aided system for leaf recognition. The important procedures which are involved in leaf identification are image processing, edge-detection, feature extraction and classification. The system used neural network and support vector machine. The system used manually captured leaves images from 10 different species and the leafsnap dataset. It concluded that the system gave better accuracy. It states that in future, the recognition performance can be improved.

Paper [12] aimed to help farmers in efficiently cultivating crops and hence achieving higher productivity at lower costs. It discussed the uses of Machine learning, Data analytics, IoT technologies to analyze soil, to identify weeds, to identify diseases, to recommend the suitable crops for cultivation, and to determine the quantity of fertilizers and pesticides needed to be used. All these are few elements of precision farming. For weed identification, the system used v2 plant seedling dataset. It used Resnet 152 V2 pre-trained keras model to classify images. It also recommended herbicide for predicted weeds. To recommend herbicide, it used the crop name and weed name as input parameters for random forest classifier.

Paper [13] aimed to utilize the vegetation indexes which are taken from multispectral leaf reflectance data as an input to differentiate the soybean and three weeds namely Palmer-amaranth, Redroot-pigweed, and Velvetleaf. 12 normalized difference vegetation indexes were taken from reflectance measurements, that include advanced, green, green-blue, green-red and normalized difference vegetation indexes, normalized difference pigment and red-edge-indices, shortwave infrared-water-stress indices and structure- insensitive-pigment index. The study supported the usage of vegetation indices and machine learning algorithms namely, c forest as decision support tools for the identification of weeds.

Paper [14] focused on controlling weeds on farms by identifying and classifying weeds. It proposed a convolution network, which is a Deep learning -based computer-vision technology. This technique has been used for evaluation of images by detecting weeds. This system involves two phases. The first phase is collection of images and labeling it. It also

involves the procedure of extracting features from the images. The second phase involves the construction of neural network model to detect weed. The input data is given to the model, its features are extracted and classified using dense layer. The dataset used is taken from the kaggle database. It suggests that this model can be extended in future to help in detecting weeds from large crops and also can be improved to detect more types of weeds and crops with accurate classification and also to involve less human effort.

Paper [15] aimed to classify weeds and crops for effective management of agriculture. It compares the classification model that is SVM and Deep learning classification model. It uses RGB image texture features for making classification. The SVM and VGG16 which are deep learning classifiers, were made use in order to classify four types of weeds nam corn, ely Horseweed, Ragweed, Kochia and Waterhemp and six crop species namely Black- bean, Canola, Soybean, Flax and Sugar-beets. This system uses weed and crop RGB dataset. According to this paper, seven different types of classifying models for weeds have been built for the supervised machine learning, SVM model and supervised Deep learning VGG16-CNN model. This study shows better results when deep learning technique was used for the classification of weeds.

Summary of Related Works:

Table.1 Summary of Related Works

INFERENCE
Paper [1]: Provides comparison of Machine learning and Deep learning. Machine Learning can be used for smaller training dataset. In Deep Learning, feature selection is automated.
Paper [2]: Gives introduction to machine learning algorithm. If the dataset is lesser and labeled, then supervised learning techniques can be used. Unsupervised learning technique can be used for large dataset. Deep Learning techniques can be applied for huge datasets.
Paper [3]: Supervised learning method is used for segmenting plant from the background in its images. Neural networks perform better in segmentation and handling

misclassifications.
Paper [4]: The comparative study of plant identification by supervised learning method using various approaches is studied. The identification of plant is done based on three different types of features that are extracted from images of leaves.
Paper [5]: Uses convolution neural network to classify weed and crop. Uses datasets that consist of images of plants at their early growth stage.
Paper [6]: Transfer Learning is used to classify crops and weeds. The observation is that size of the input image has an effect on the performing ability of the model.
Paper [7]: More images lead to better results. It uses modified VGG16 which can be applied for three functions namely, training the network, use of transfer learning to leverage features obtained from VGG16 and fine-tuning the network
Paper [8]: It demonstrates that transfer learning enhances the performing ability of deep learning. It states that transfer learning techniques should be used in case of low performance, instead of using end to end CNN.
Paper [9]: It implies that the weed classification can be used to develop an automated weed removal system. The input image from the camera is processed to find the area of interest. This region is cropped and used in CNN for classification.
Paper [10]: It provides the comparative analysis of various algorithms that can be used for weeds classification. The observation states that transfer learning gives better results and yolo-v3 algorithms are best for object detection.

Paper [12]: The features that include shape and texture are used. It suggests the use of leaf recognition for classifying plants.
Paper [13]: Resnet 152 V2 with CNN is used to classify images. It also uses a technique namely the skip connection to skip some of the phases of training and to connect to output.
Paper [13]: Vegetation indices are used as input variables to classify crop and weed. Vegetation indices are less influenced by shadowing and sensor viewing angle.
Paper [14]: CNNs are trained to recognise the best features of the input image and to extract them. It states that when the number of epochs increases, the accuracy increases.
Paper [15]: It compares VGG 16 and SVM classification model to classify crop and weed. It states that VGG16 provided better results.

3. Research Methodology

The research data was obtained from Kaggle Website. The DeepWeeds dataset consists of 9 classes. 8 classes of weeds and one negative class. The dataset consists of 17,509 images [16]. The labels are given in a separate file as shown in Figure 1. The classes of weeds include Parkinsonia, Prickly Acacia, Siam weed, Snake weed, Chinee apple, Rubber wine, Parthenium, and Lantana, which are shown in Figures 2 to 10.

Filename	Label	Species
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20160928	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
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20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple
20161207	0	Chinee apple

Figure 1. Labels

Figure 2. Chinee apple

Figure 3. Lantana

Figure 4. Parkinsonia

Figure 5. Parthenium

Figure 6. Prickly Acacia

Figure 7. Rubber Wine

Figure 8. Siam Weed

Figure 9. Snake Weed

Figure 10. Negative

The proposed system uses Convolutional Neural Network architecture as shown in Figure 11 and provides the comparison for classification. It is a type of neural network. It is utilized for the analysis of the visual images in the way of processing data using a grid like topology.

- The image pixels are fed into the convolution layer.
- It gives a convolved map.
- The ReLu activation function is applied on the convolved map.
- The multiple convolution layer and ReLu function are used to process the image.
- Then the image is applied to the Pooling layer.
- Then the pooled feature map is flattened, and it is given into the fully connected layer for classification.

Input Layer

The input layer refers to the input image that is fed into the CNN. The input images used are the RGB images. The RGB images present in the input layer consists of three channels, namely the red channel, green channel, and blue channel.

Feature Extraction

Convolution is one of the most important building blocks of the CNN. Convolution is the mathematical operation of two functions which produces a third function. The convolution function is performed on the input data with the use of the filter or the kernel. Convolution involves searching of the image by the way of moving the filter (kernel) across the image in order to find different features present in the image. It then results in a feature map. At each location, product of the matrix is performed, and the results are added to produce the feature map.

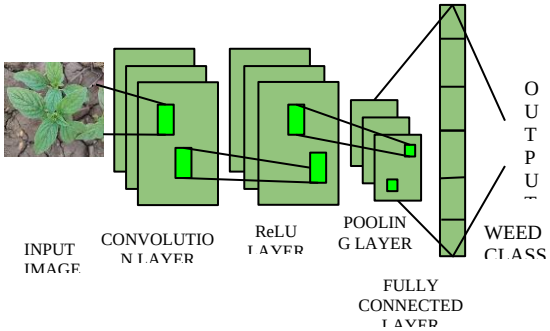


Figure 11. Proposed Architecture

Parameters

Kernel size is the filter size. It refers to the dimensions of the sliding window over the input image. Small kernel sizes enable the model to extract a large amount of information about features present in the input image. A smaller kernel size results in smaller reduction in layer dimensions. A large kernel size extracts only less information from input image, and results in larger reduction in layer dimensions.

Stride refers to the number of pixels the kernel should slide at a time. When the number of strides is decreased, more features are extracted and learned. This results in larger output layers. When the number of strides is increased, only limited features are extracted and results in smaller output layer dimensions.

Pooling Layer

Pooling-layer is used in CNN in order to decrease the dimension of the image by reducing the number of parameters and the computation in the network.

Dropout Layer

Dropout layer is used in order to prevent the problem of overfitting.

Dense Layer

The dense layer is a layer that is used in CNN, which is connected to its previous layer such that it gets output from the previous layer as input to it. Based on this, it classifies the images.

Batch Normalisation

Batch normalization is used in CNN in order to increase the speed of training and to make learning easier.

Activation Functions

ReLu

Rectified Linear Unit (ReLu) makes the models learn fastly and improves the performance. It is used as the default activation function when using CNN.

Softmax

The Softmax function is usually used at the end (output) layer of the neural network. It is used for multiclass classification. It gives the probability for each class.

Implementation of Proposed Approach

Framework:

Tensorflow

It is a framework which is made use in Machine learning, and deep learning models. It is open sourced. It is meant to integrate API to build and train Deep learning architectures.

Library:

Keras

It is an API of Deep learning methodology. It is mainly used for the development and evaluation of deep learning models.

Data Preprocessing

Data preprocessing method used in this research is the Data Augmentation technique. It is used for preprocessing the data. It involves rescaling, rotating, flipping, shearing, and zooming of input image. It is used to get different views of the data and to increase the quantity of data which can lead to the improvement in performance of the mode and the accuracy.

Training and Testing data

The data allocated for training is eighty percent and data allocated for testing is twenty percent.

Model Building

ResNet

Residual Network (ResNet) is one of the Deep learning models. It is a CNN architecture. It is used to solve the problem of vanishing gradients. It uses a technique called 'skip connection', which means identity mapping. The input from the previous layer is directly added to the output of the other layer. The main benefit of ResNet is that the networks that have a very large number of layers can be trained easily without incrementing training error. ResNet is of various forms which has varying numbers of layers namely, ResNet-18, ResNet-50, ResNet-110, and ResNet-152.

MobileNet

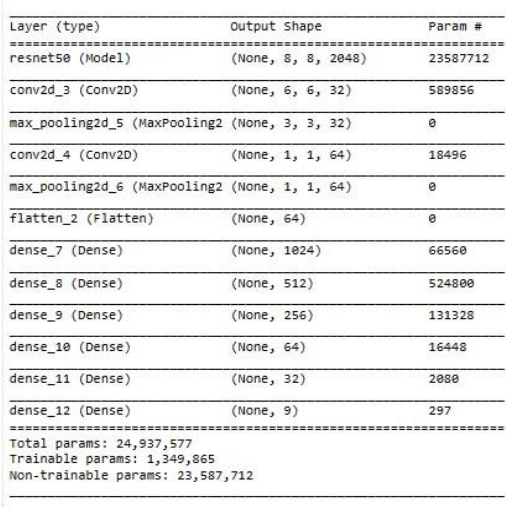
MobileNet is a CNN architecture. It uses depth wise separable convolutions. It constructs lightweight deep convolutional neural networks which can have low latency. It is said to provide an efficient model for mobile applications and embedded vision applications.

InceptionNet

Inception network is one of the CNN model. It is meant for efficient computation and deeper networks by reducing dimensions. It is designed to solve the problem of computational expenses.

4. Results and Discussion

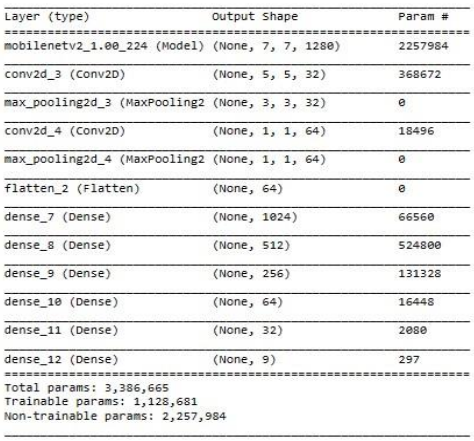
The system is built by preprocessing the images and generating the training data and the testing data. Then ResNet50 as shown in Figure 12, MobilenetV2 as shown in Figure 13 and InceptionV3 as shown in Figure 14, are used for classification.



Layer (type)	Output Shape	Param #
resnet50 (Model)	(None, 8, 8, 2048)	23587712
conv2d_3 (Conv2D)	(None, 6, 6, 32)	589856
max_pooling2d_5 (MaxPooling2	(None, 3, 3, 32)	0
conv2d_4 (Conv2D)	(None, 1, 1, 64)	18496
max_pooling2d_6 (MaxPooling2	(None, 1, 1, 64)	0
flatten_2 (Flatten)	(None, 64)	0
dense_7 (Dense)	(None, 1024)	66560
dense_8 (Dense)	(None, 512)	524800
dense_9 (Dense)	(None, 256)	131328
dense_10 (Dense)	(None, 64)	16448
dense_11 (Dense)	(None, 32)	2080
dense_12 (Dense)	(None, 9)	297

Total params: 24,937,577
Trainable params: 1,349,865
Non-trainable params: 23,587,712

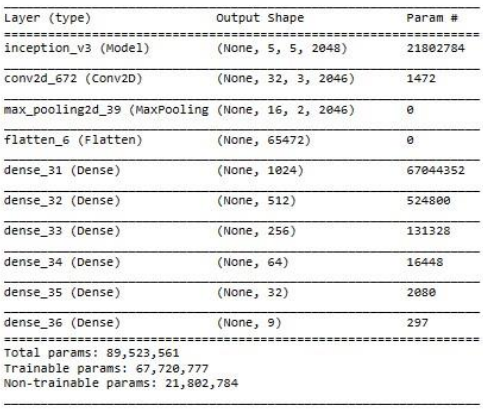
Figure 12. ResNet50 architecture



Layer (type)	Output Shape	Param #
mobilenetv2_1.00_224 (Model)	(None, 7, 7, 1280)	2257984
conv2d_3 (Conv2D)	(None, 5, 5, 32)	368672
max_pooling2d_3 (MaxPooling2	(None, 3, 3, 32)	0
conv2d_4 (Conv2D)	(None, 1, 1, 64)	18496
max_pooling2d_4 (MaxPooling2	(None, 1, 1, 64)	0
flatten_2 (Flatten)	(None, 64)	0
dense_7 (Dense)	(None, 1024)	66560
dense_8 (Dense)	(None, 512)	524800
dense_9 (Dense)	(None, 256)	131328
dense_10 (Dense)	(None, 64)	16448
dense_11 (Dense)	(None, 32)	2080
dense_12 (Dense)	(None, 9)	297

Total params: 3,386,665
Trainable params: 1,128,681
Non-trainable params: 2,257,984

Figure 13. MobilenetV2 architecture



Layer (type)	Output Shape	Param #
inception_v3 (Model)	(None, 5, 5, 2048)	21802784
conv2d_672 (Conv2D)	(None, 32, 3, 2046)	1472
max_pooling2d_39 (MaxPooling	(None, 16, 2, 2046)	0
flatten_6 (Flatten)	(None, 65472)	0
dense_31 (Dense)	(None, 1024)	67044352
dense_32 (Dense)	(None, 512)	524800
dense_33 (Dense)	(None, 256)	131328
dense_34 (Dense)	(None, 64)	16448
dense_35 (Dense)	(None, 32)	2080
dense_36 (Dense)	(None, 9)	297

Total params: 89,523,561
Trainable params: 67,720,777
Non-trainable params: 21,802,784

Figure 14. InceptionV3 architecture

All the three methods resulted in the following values of accuracy which is shown in Table 1.

Table 2. Classification Accuracy Scores

Epochs	Accuracy of ResNet50	Accuracy of Mobilenetv2	Accuracy of InceptionV3
5	56.1%	55%	57.75%
10	68.9%	63%	62%
15	81.25%	72.93%	75%

5. Conclusion and Future Work

The models for weed classification have been developed using different CNN architectures. The work done involves finding data, preprocessing data, allocating data for training and testing, building models using three different CNN architectures such as ResNet50, MobileNetV2 and InceptionV3, which provide solutions with accuracy 81.25%, 72.93%, and 75% respectively to classify eight types of weeds. The same technique can be deployed to develop models for classifying other types of weeds across different places.

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