Computerized Growth Analysis of Seeds Using Deep Learning Method

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Abstract: Seed Germination is ideal and most important for seed quality which has an impact on its production as well as its yield. Presently germination rate calculation is done manually with the help of trained persons which is a very tiresome process. Through this project, we present a system for computerized and automatic determination of germination rate using some high-level techniques in computer vision and machine learning. We analyze the germination rate of seeds by comparing it with a large number of datasets comprising of germinated and non-germinated samples using neural networks. This analysis is done by considering the root of the germinated seed. Therefore this method is known as Multi-Level Root Metric Ratio(MLRM) method.

Index Terms: Computer vision, Machine Learning, Multi-Level Root Metric Ratio method

I.INTRODUCTION

There are a number of non-destructive methods that were developed to monitor the seed quality. Among these methods, most of them focussed on variety identification, classification, and disease assessment. A germination test is commonly used and most reliable method to access viability. Germination is a process through which a plant grows from a seed. Sprouting of a seedling is the most common example of the process of germination. Water, Light, oxygen, temperature are the factors necessary for germination of a seed. Seed germination experiments are conducted in a variety of biological disciplines. This includes studies of physiological processes, types, and control of dormancy, histories of plant life, genetic induced and environmentally induced differences between the population, storage of seeds or preparation methods that produce an increase in germination percentage.

Germination process is usually carried out by placing a pile of seeds on a wet substrate inside a box. After a specified period of time seeds are examined for germination and the germination is predicted with the help of experienced persons. Germination rate is a measure of how many seeds have germinated over a specified period of time out of the entire amount of seeds taken for the germination process. It is usually expressed as a percentage. The germination paper that is used for the process of germination is being selected based upon proper chemistry characteristics. In short, Germination refers to a physiological and developmental process of a seed that stops its maturity when it is affected by factors such as water availability, temperature, and other physiochemical effects.

Manual methods of evaluating germination rate are hard as it requires experienced persons, and there might be overlapping of seeds and its parts namely leaf, root, and stem. In this paper, we present a system which is a non-destructive as well as automated for germination rate evaluation. This is done by capturing images and processing them through image processing and comparing with the available datasets[5].

II. MOTIVATION

Germination rate measurement is an important parameter for good growth of seeds. By determining the germination rate in a computerized way, seeds that are not suitable for germinating process are eliminated and by this we can achieve higher productivity and by predicting the duration of its growth, we can perform the crop rotation process in a more efficient way that is we can decide when to sow the next seed if we know when the current seed will mature[3].

III. CONTRIBUTION

To achieve higher productivity and to grow good quality seeds and to ease the process of manually computing germination rate we present a system that is computerized through which germinated seeds images are captured and pre-processed and the processed image is segmented and the segmented part is trained using neural networks and is compared with the available datasets using neural networks to compute the germination rate[9].

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IV.LITERATURE SURVEY

A. "A Vision-Based Method for Automatic Evaluation of Germination rate of Rice Seeds" – ThuyThi Nguyen, Van Nam Hoang, Thi-Lan Lee, Hai-Vu

- Germination rate measurement is an important parameter for the growth of the seed[1].
- It is a tedious process when done manually with the help of experienced persons.
- This paper presents an automatic and non-destructive method which uses U net Convolutional Network for segmentation and separation of the rice seeds.
- Further processing such as distance transform calculation and thresholdingis applied on the segmented portions of the rice seeds.
- ResNet is used to classify the seeds into two namely germinated and non-germinated seeds.
- The drawback is that it contains only limited data sets.

B. "Deep Residual Learning for Image Recognition" – K. He, X. Zhang, ShaoqingRenJian Sun

- Deep Neural Networks are generally hard to train.
- Here, a residual framework is used to ease the process of training the networks.
- Optimization is very much easier for Residual Networks.
- It can also gain accuracy from increased depth as well[2].

C. "Measurement of Seedling Growth Rate by Machine Vision" – M.S.Howarth, P.C.Stanwood

- Traditionally, seed vigor and germination tests have been done to analyze the deterioration of seed.
- Vigor tests are done to analyze the potential of the seed to emerge and result in a mature crop under certain field conditions.
- A machine vision based system is developed to measure the growth rate of the root over the complete germination period
- This Machine vision system minimizes human effort and minimizes problems such as eye fatigue, decision differences, etc.
- The results were compared with the traditional test results and were found to be similar.

D. "U-Net Convolutional Networks for Biomedical Image Segmentation" – Olaf Ronneberger, Philipp Fischer, Thomas Brox

- Training of deep networks requires thousands of training samples.
- Here in this paper, a network is presented that depends on the strong use of data augmentation to use the available samples more efficiently for training.
- The architecture comprises of a contracting path and an expanding path.
- Using U net the network can be trained from end to end from very few images and it outperforms other prior methods
- This method is very fast. Segmentation takes only about seconds.
- The drawback is that it shows a delay as it much runs separately for different patches and there also exists a degradation problem[4].

V.EXISTING SYSTEM

In the existing system, the seeds need to be separated from the germination sheet using a special detection process. This process is complex as the seeds that are spread on the germination sheet are not uniform and when the seeds germinate, their parts may overlap. Also in the existing design [1], U-net convolution network is being used. The common use of a convolutional neural network is for the classification task.

U-net is an elegant architecture that was mainly developed for the purpose of the biomedical image segmentation process. The main concept behind it is to supplement a common contracting network by successive layers. Here the pooling operations are replaced by up sampling operators. These layers increase the resolution of the output and a successive convolutional layer can learn to arrange an actual output based on this information. The network consists of both a contracting path and an expansive path, which provides it with U shaped structure. The contracting path consists of a repeated application of convolutions followed by rectified linear unit and a maximum pooling operation. The contraction process decreases the spatial information while increasing the feature information whereas the expansive path combines the spatial and feature information through a sequence of up convolutions and concatenations[10].

There is no presence of dense layer in U-Net, therefore, images of various sizes can be used as input and it also allows massive data augmentation which is important for biomedical segmentation.

In the existing work [1], the entire image of the germinating seeds that is captured from the germination sheet is used as an input to the U-net. The output of which is a segmented map in which the value of each pixel represents the probability whether the pixel belongs to a seed. To obtain the final results distance transform and thresholding functions are being applied. For Classification of seeds, deep residual networks consisting of 101 layers named as ResNet- 101 is being used which uses a pre-trained model on image net dataset and fine tuning with the current dataset.

VI.PROPOSED SYSTEM

The proposed framework has two steps in general namely seed detection and seed classification. Two seeds may lie close to each other which will be hard to separate using object detection algorithms. Also U net does not produce the desired level of accuracy needed and also there is delay and degradation problem so we move onto deep neural networks. The architecture of neural networks consists of

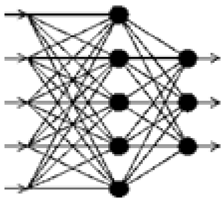


Figure 1. Feed Forward Network

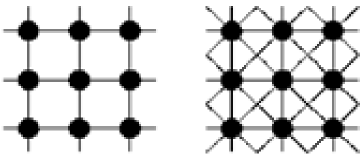


Figure 2. Feedback Network

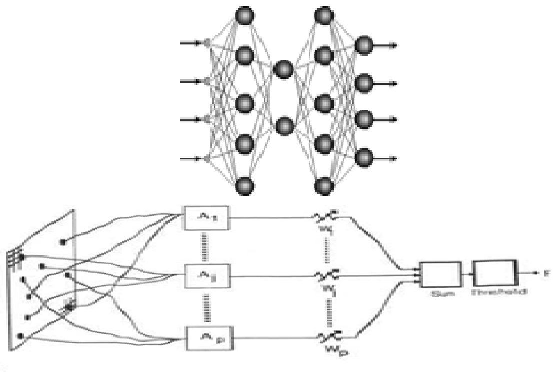


Figure 3. Perceptron

A.Feedforward Networks

It allows signals to travel in only one direction i.e. from input to the output which is shown in figure 1. There is no presence of a feedback loop and so the output of that layer does not affect that layer. They are considered to be straight forward networks that associate outputs with inputs. This approach is referred to as bottom-up or tops down approach. They are mainly used for pattern recognition.

B.Feedback Networks

These networks can have signals travelling in both the direction with the help of loops in the network and is represented in figure 2. These networks are very dynamic and powerful but they can get pretty complicated as well. They change state continues until the required equilibrium is reached and they remain in that equilibrium until the input changes and then a new equilibrium has to be found, Feedback architectures are also known as recurrent or interactive architectures.

C.Network Layers

The most common type of neural network consists of three groups or layers of units that is a layer of the input unit is connected to a layer of the hidden unit which in turn is connected to a layer of the output unit. The input unit consists of the raw information that is fed into the network. The activities or functions of the hidden unit is determined by the activities or functions of the input unit and the weights of the connections between the hidden and the input units. The activities of the output unit depending on the activities of the hidden units and weight of connection between the hidden and the output unit. Hidden nodes are free to construct their own representations of the input which makes this network quite interesting. The weights between the hidden and the input unit help to determine when each of the hidden units is active and by changing these weights the hidden units can choose what it represents. In the single layer organization, all the units are connected to one another whereas in multi-layer networks units are numbered by layers.

D.Perceptrons

The term perceptrons were coined by Frank Rosenblatt and are represented in figure 3. It is an MCP model with some additional fixed pre-processing. From the figure, the units labeled A1, A2, Aj, and Ap are known as association units and their functions include extracting certain specific localized features from the input image. They were mainly used for pattern recognition while their capabilities were way more. In 1969, Minsky and Papert wrote a book that described the disadvantages of single layer perceptrons which made a number of authors lose interest. Mathematically, it is proved that single layer perceptrons could not do some basic tasks like determining the parity of the shape and determining whether the shape is connected or not. But multi-layer perceptrons can do these tasks. Multi-layer perceptron is mainly used for classification or prediction methods of data mining. The user generally wants the network to split the input into several groups. Some of the necessary steps of the life cycle include

- Preparing Data
- Preparing Network
- Training Network

- Classifying

The network is trained using back-propagation algorithm with many parameters to tune the network well. Only numbers can be used to train the network namely binary that is 0, 1.

E.Back-Propagation Algorithm

We consider training a multi-layer perceptron for pattern association using the back-propagation algorithm. We assume a set of pattern pairs or associations: $s^{(q)}$: $t^{(q)}$ where q=1, 2….and so on.

The training vectors $s^{(q)}$ has 'N' components shown in equation [1]

$$S^{(q)} = [S_1^{(q)} \; S_2^{(q)} \; \ldots\ S_N^{(q)}] \ldots\ldots\ldots\ldots [1]$$

And their targets $t^{(q)}$ have been' Components shown in equation [2]

$$t^{(q)} = [t_1^{(q)} \; t_2^{(q)} \ldots\ldots t_o^{(q)}] \ldots\ldots\ldots\ldots [2]$$

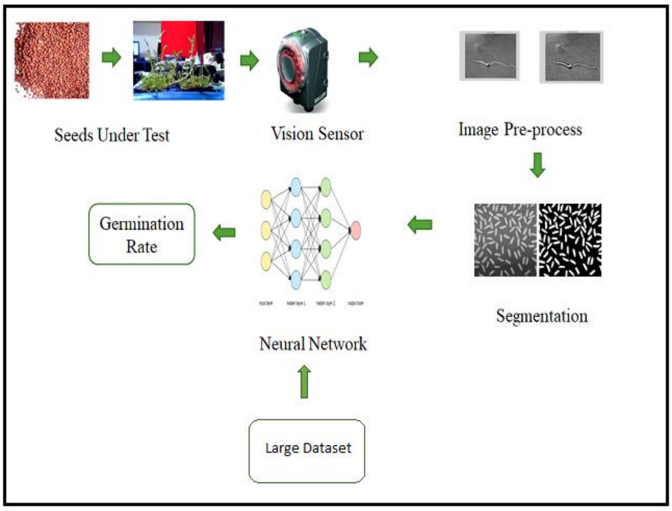
As in Delta rule, the training vectors are presented one at a time to the network during the training process. Suppose in a time step t during the training process, a training vector s (q) is presented as an input x (t) for a particular q to the network. The input signal can propagate forward through the network using these equations and the set of weights and biases to obtain the corresponding output y (t). The weights and biases are then adjusted in the L^{th} layer. $n^{(L)}$ gives the activations of the previous layer and the weights and biases of layer L.

The explicit relation is given at equation [3] and [4]

$$\begin{aligned} E &= \|y - t(t)\|^2 = \|a^{(L)} - t(t)\|^2 = \|f^{(L)}(n^{(L)}) - t(t)\|^2 \\ &= \left\| f^{(L)}\left(\sum_{i=1}^{N_{L-1}} a_i^{(L-1)} w_{ij}^{(L)} + b_j^{(L)} \right) - t(t) \right\|^2 . \end{aligned} \quad \ldots [3]$$

$$\frac{\partial E}{\partial w_{ij}^{(L)}} = \sum_{n=1}^{N_L} \frac{\partial E}{\partial n_n^{(L)}} \frac{\partial n_n^{(L)}}{\partial w_{ij}^{(L)}} . \quad \ldots. [4]$$

F. Architectural design



In the proposed system, as shown in the architectural design images are captured using a vision sensor and they are processed which consists of three steps namely

- Grayscale conversion: Here we convert the input image into a greyscale image to reduce the pixel size which makes the segmentation process easy. RGB is converted to gray using the following algorithm

  0.2989*R+ 0.5870*G + 0.1140* B

- Filtering: Filtering is done to remove in the image that arises after greyscale conversion. It is done using a median filter which is an effective method that can distinguish up to a certain extent the out of range isolated noise from the legitimate image features like edges and lines.

  To be more accurate, it replaces a pixel with the median rather than the average of all the pixels in the neighbourhood w shown at equation [5]

$$y[m,n] = median\{x[i,j], (i,j) \in w\} \quad \ldots. [5]$$

Where *w* represents a neighbourhood defined by the user-centeredon location m, n in the image. Enhancement: Enhancement process is done to increase the quality of the image. Sharpening process is carried out here. After which segmentation of the root is done which gives rise to the method Multi-Level Root Metric ratio method (MLRM). Segmentation is carried out using the method of Region of Interest.

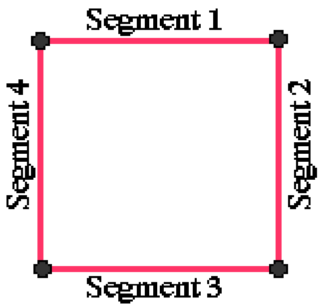


Figure 4 ROI Line Segments

Segmentation is done to simplify or to change the representation of an image into something more meaningful and easy to analyze. Image segmentation is a process of assigning a label to every pixel in an image such that pixels that have the same label share similar characteristics. For ROI's that enclose an area, each ROI is defined by the outline that encloses the region. To make the computation of ROI statistics easy, all the line segments of the ROI must be straight as shown in figure 4. Spline and Elliptical ROI's would be problematic and slow. Calculating of intensity statistics for them are done by representing the outline by a series of straight line segments. For elliptical ROI if the outline is represented by 'n' straight line segments then the error between the approximated area and the true are of the ellipse is computed as follows as shown in equation [6]

$$(\pi - (n * \sin(\pi/n) \times \cos(\pi/n))) \times 100\% / \pi \qquad \text{... [6]}$$

Computing intensity statistics for ROI's involves multiplying pixel intensities with the area of the pixels that line within the outline of the ROI. There is an expected error of 0.005% for an elliptical ROI.

For spline ROI's, the interpolated spline shape is distributed among a thousand straight line segments and the statistics that are gained are similar to those of a polygon shape with these segments. The vertices of an ROI outline could be positioned anywhere with reference to the array of image pixels, so the same rectangular ROI shown in figure 4 may appear as figure 5

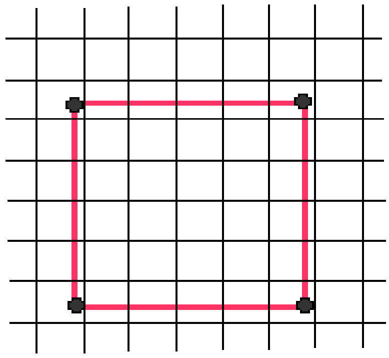


Figure 5 Positioning of ROI vertices

Finally, the segmented image of the root undergoes a process of training and is compared with the available datasets using the neural network which is done using the back propagation algorithm to determine the germination rate.

VII.EXPERIMENTAL RESULTS

The seed is soaked in water for some duration of time and spread over a germination sheet which is kept moist.

Figure 6. Input image

Figure 7. Grayscale Conversion

Figure 8 Filtered Image

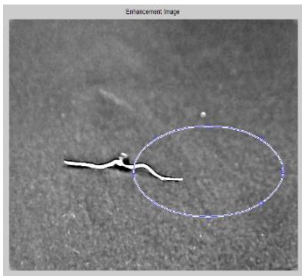


Figure 9 Image Pre-processing

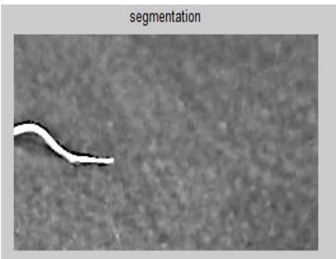


Figure 10 Segmented image

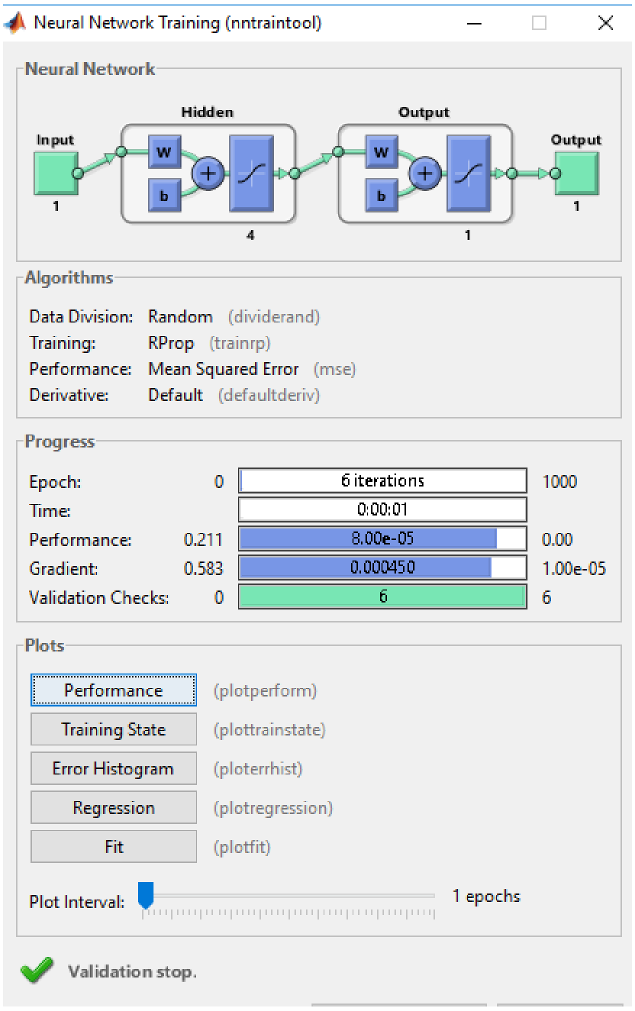


Figure 11 Neural network training module

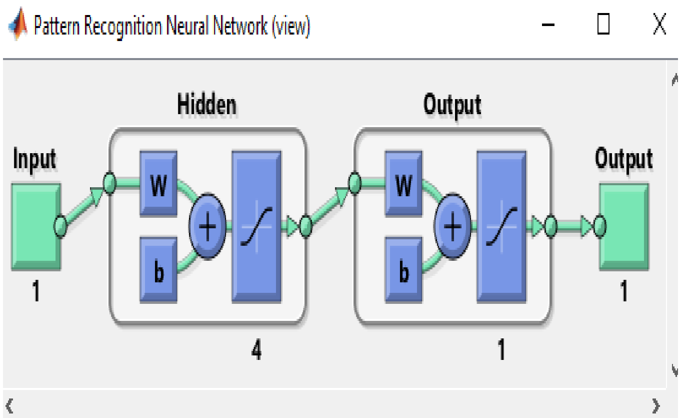


Figure 12 Pattern Recognition Neural Network

```
cm =

     0     0
     1     3

Accuracy : 75.000000
Water Content:400-450 mm;Time to grow:3-5 Months>
```

Figure 13 Germination Rate Accuracy

The seed is absorbed for germination and images are captured which is shown in figure 6 The image is then processed by converting it into greyscale and then filtering and enhancing it which is depicted in figures 7,8,9.

The desired portion for analysis of the germination rate that is the root is then segmented from the enhanced image as shown in figure 10. The image is then trained, tested and validated which is shown in figures 11 & 12. Figure 11shows the number of iterations that are required to match the input with the dataset to attain the best result. The germination accuracy is shown in figure 13 along with essential parameters for satisfactory growth of a ragi seed

This process is carried out for various seeds namely ragi, fenugreek, chickpea, horse gram, sesame, green gram which have a number of medicinal uses. More information that is necessary for the proper and healthy growth of these seeds like water content, soil, fertilizers to be used, number of days to germinate, number of days to mature and temperature are displayed attable 1.

Seed	**Soil**	**Water Content**	**Germination Period**	**Maturing Period**	**Fertilizers**	**Temperature**
Ragi	Red Lateritic soil	400-450mm	8 Hours	3-5 Months	Azospirillumbrasilense and Aspergillusawamori	27 °C
Green Gram	Red lateritic soil or Black Soil	Irrigate at intervals of 7 to 10 days	Within 24 hours	60-90 Days	5 Kg of Nitrogen, 16 Kg of P205 per acre at the time of sowing	25 – 35 °C
Chickpea	Fertile Sandy loam to clay loam soil	Light irrigation is recommended	3-4 Days	100 Days	Diammonium phosphate at the rate of 100 to 150 kg per hectare	24 -30 °C
Fenugreek	Loamy or Sandy loamy soil	Regular watering but do not overwater it	3-5 Days	30- 40 Days	Fish Emulsion Spray	10 -32 °C
Horse gram	Black cotton or deep red loam or clay loam soils	Soil must be kept moist by frequent watering	2-3 Days	4-6 Months	One packet of Rhizobial Culture and one packet of Phosphobacteria	20 -30 °C
Sesame	Well Drained light to medium textured soil	350-400mm	2-3 Days	3-5 Months	Spread FYM or composted coir pith	25 -35 °C

Table 1: Requirements for satisfactory growth of a seed

VIII.CONCLUSION

Germination rate is very much necessary to analyze the growth quality of the seeds and to predict the duration of its growth rate. In this paper, we have devised a computerized method for determining the germination rate using neural networks and computer vision. We have captured images processed them and segmented them and analyzed them by comparing them with the available

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datasets using Neural networks. Also in the proposed work, we have tested this system for several seeds which are filled with medicinal uses and we have also trained the network by feeding it with a rich set of data sets.

IX. FUTURE SCOPE

In the present work, we capture separate images of seeds and pre-process them and segment them and analyze them by training them and comparing them with the available data sets using neural networks. This process is a disadvantage when needed to analyze seeds for an acre or half acre land as capturing single images of seeds is difficult when the number of seeds is large. In the future work, we will try and capture 10 to 20 seeds on a single image and analyze them to determine the germination rate which will be suitable for an acre or half an acre of land.

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