

PDCNN: FRAMEWORK for Potato Diseases Classification Based on Feed Forward Neural Network

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Abstract:

The economy is exceptionally reliant on agricultural productivity. Therefore, in domain of agriculture, plant infection discovery is a vital job because it gives promising advance towards the development of agricultural production. In this work, a framework for potato diseases classification based on feed forward neural network is proposed. The objective of this work is presenting a system that can detect and classify four kinds of potato tubers diseases; black dot, common scab, potato virus Y and early blight based on their images. The presented PDCNN framework comprises three levels: the pre-processing is first level, which is based on K-means clustering algorithm to detect the infected area from potato image. The second level is features extraction which extracts features from the infected area based on hybrid features: grey level run length matrix and 1st order histogram based features. The attributes that extracted from second level are utilized in third level using FFNN to perform the classification process. The proposed framework is applied to database with different backgrounds, totally 120 color potato images, (80) samples used in training the network and the rest samples (40) used for testing. The proposed PDCNN framework is very effective in classifying four types of potato tubers diseases with 91.3% of efficiency.

Key words: First order histogram features, Gray level run length matrix, K-means clustering algorithm, Potato diseases, Scaled conjugate gradient backpropagation.

Introduction:

High quality of agricultural crop is one of main factors in food, exportation, health and food industry. Potato is a substantial vegetable crop, it is an integral part of our food after rice, wheat, and maize. Therefore, the nutritional value of traditional foods and the utilization of potato are expected to be improved by substituting wheat, rice or maize in traditional staple foods partly by potato(1).

All potato species are clones disseminated vegetative by tubers which are unprotected to a vast range of pathogenic organisms, which transmit from plant to another plant. The pathogens may be fungi, bacteria or viruses. Damages can occur when plants are growing, at hoisting and when tubers are stored. Some diseases do not devastate potato tubers, but they cause surface blotches which reduce sellable value(2). Most of plant diseases result from

complicated fundamental interactions among a pathogen, a vulnerable host plants and plants environment(3). Plant diseases may cause comprehensive destruction of the plant under circumstances appropriate for the disease. Diseases of plants can be classified into: bacterial diseases, viral diseases and fungal diseases(4).

Early detection of potato diseases is a big challenge in “agriculture science”, these diseases can cause substantial loss within a few days. To prevent heavy loss in agricultural crops, fast detection of these diseases is necessary. Farmers can detect diseases using their eyes but this process is tedious, time consuming and impractical in large farms. So, a reliable, fast, and automatic system is required to detect these diseases accurately. In this work, a PDCNN Framework has been proposed to

classify four types of potato tubers diseases; which are: “black dot” which is one of fungal diseases caused by the fungus *colletotrichum coccodes*, “common scab” which is caused by pathogenic streptomyces species, “potato virus Y” which causes a range of symptoms in potato, “early blight” which is one of fungal diseases caused by *alternaria solani* sorauer(4) as illustrated in Fig.1. The presented framework; passes in three main levels: pre-processing is the first level, the second one is features extraction and the third level is classification. The first level aims to extract the infected area from the potato images based on K-

means clustering algorithm. The second level, computes hybrid features of the infected areas. While the third level uses two layer feed forward neural network with scaled conjugate gradient backpropagation (SCG-BP) learning algorithm to classify the disease type.

Eventually, this work has been organized as follows: second section reviews some of related works. Third section explains in details the three levels of presented PDCNN framework. Fourth section explains in details the results and discussions of PDCNN framework. The conclusion is illustrated in fifth section.

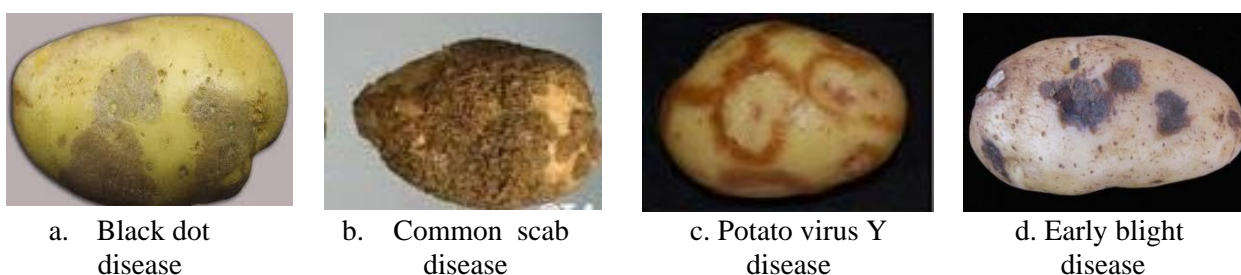


Figure 1. Four Kinds of Potato Tubers Diseases

a. Black dot disease, b. Common scab disease, c. Potato virus Y disease and d. Early blight disease.

Related Works:

Many recent researches deal with potato crop, monzurul Islam et al. (5) presented a system to detect only two potato diseases (late blight, early blight) or absence thereof based on leaf images, images of potato leaves with plain background were used, segmentation technique was used to extract region of interest that only contains visible diseases symptoms, the gray level co-occurrence matrix (GLCM) was used for feature extraction, classification process was performed by using SVM, the accuracy of their approach was 95%. Ryo Sugiura et al. (6) presented a new mechanism in potato fields, aerial images from an unmanned aerial vehicle were used, they developed an image processing protocol to estimate the late blight disease severity of potato crop, their method provided a precise and objective results. Yongsheng Si et al. (7) presented a new technique of potato tubers estimation based on “length to width ratio”, they utilized watershed method in segmentation stage, the results of their method indicated accuracy of 94% for russet; 96% for white tubers and 84% for red tubers. Francine C. A. Pacilly et al. (8) proposed an approach to analyze late blight management, their approach aimed to identify paramount aspects in late blight disease controlling by using each of fuzzy cognitive map and

stakeholder interviews. Ciprian-Radu Rad et al. (9) presented a system helping farmers in agriculture management, the system can observe vegetation conditions of potato which help farmers to make suitable decisions to improve agricultural productivity. Hu Yh et al.(10) developed least squares-support vector machine(LS-SVM) models that used to detect late blight disease, 60 potato leaves (healthy and infested) were obtained, preprocessing methods such as smoothing, normalization, derivative and baseline were used, region of interest (ROI) was extracted, spectroscopic transformation was performed, the results showed that their approach detected late blight disease effectively. Girish Athanikar and Priti Badar (11) proposed an approach based on K-Means Clustering, (GLCM), and (BPNN) for classify potato leaves, 150 images were used (50 images were healthy and 100 images were infected), their approach successfully detected the disease spots in potato leaves.

The Present PDCNN Framework

This section elaborately explains the methods and algorithms, which have been utilized in PDCNN Framework to classify the infected potato tubers for four types of diseases; as illustrated in Fig. 2.

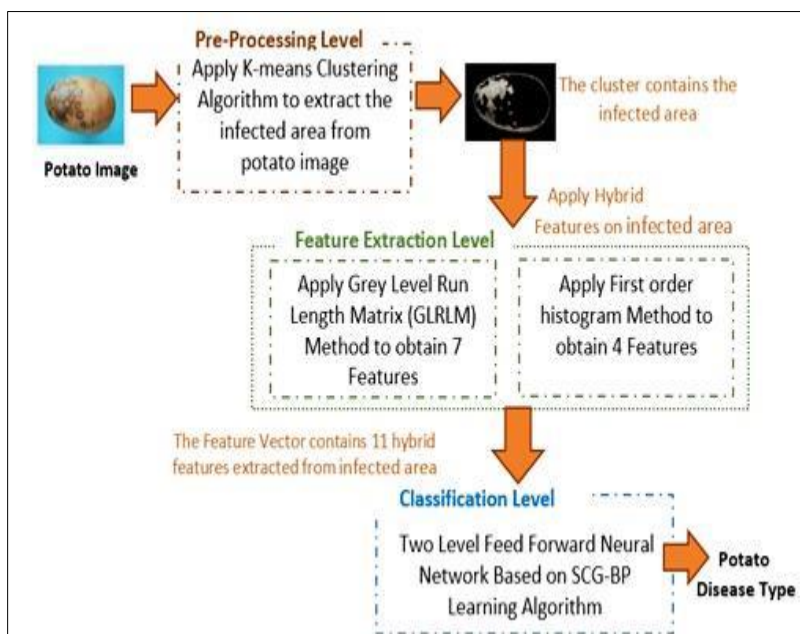


Figure 2. The Presented PDCNN Framework Levels

Pre-Processing Level

The objective of pre-processing level is to extract the infected area from color potato images which were acquired using "Sony Cyber-shot DSC-RX100 digital camera", this level consists of four main steps: firstly, apply histogram equalization; to improve images quality. Secondly, resize images in order to equalize the images size, thirdly; transform the RGB images to CIELAB color space images.

Finally, extract the diseased portion of the images from the healthy portion based on the K-means clustering algorithm(12) (13). The K-means algorithm has essential benefit of being easy and fast implement. However, clustering results depend on the selection of initial centers. So that, the selection of start center values should be done properly for getting best segmentation, as illustrated in Fig. 3.

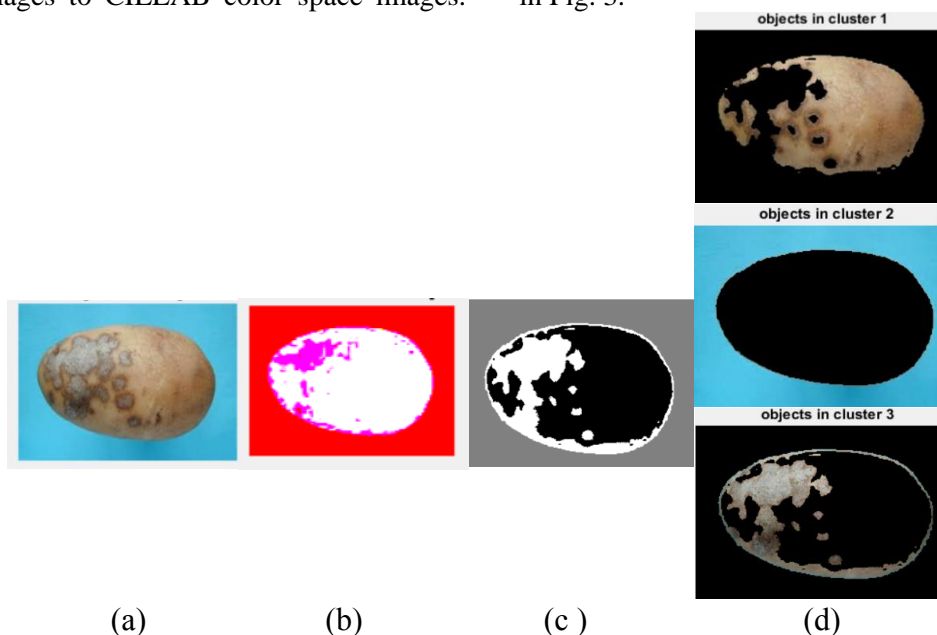


Figure 3. Potato Diseases Detection Level a) Image of black dot disease for potato in RGB color space; (b) Image of black dot disease for potato in CIELAB color space; (c) The colors classification and labeling process; (d) The three clusters

Features Extraction Level

Two significant techniques have been utilized to extract hybrid features from the infected area.

These techniques are: the grey level run length matrix and the first order histogram based features.

Grey Level Run Length Matrix

The Grey Level Run Length Matrix (GLRLM) is an effective method can be utilized to extract texture features. These features are appropriate and quite improved in symbolizing texture coarseness depending on the gray-level intensity of neighboring pixels. GLRLM is (2D) matrix which can be represented by: gray level (GL), run-length (RL) and direction (θ). The gray level run represents

a number of sequential pixels with similar (GL); (RL) is the number of pixels in a run; direction is one of four orientations such as (0° , 45° , 90° and 135°). The basic idea of this technique is calculating the number of connected pixels, which have the same gray intensity in a same direction. In a single image different run-length matrices may be computed, one matrix in each direction (14). Figure 4 explains an example of this technique.

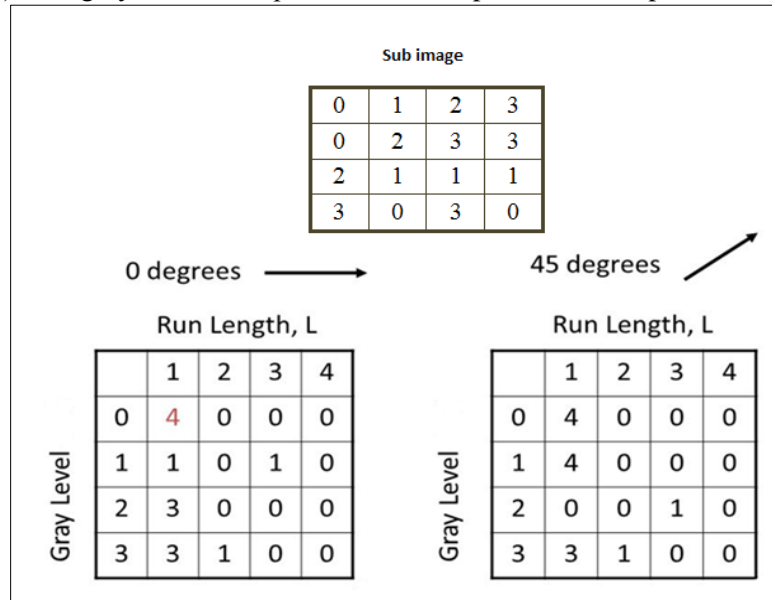


Figure 4. The Run Length Matrix Calculation for (4×4) Image in Two Direction: 0, 45 for Four Gray Levels.

Once the matrix computed, seven features are calculated from it. As illustrated in the following equations:

$$SRE = \frac{1}{k} \sum_{v,e} \frac{q(v,e)}{e^2} \quad (1)$$

$$LRE = \frac{1}{k} \sum_{v,e} e^2 q(v,e) \quad (2)$$

$$GLN = \frac{1}{k} \sum_v (\sum_e q(v,e))^2 \quad (3)$$

$$RPERC = \sum_{v,e} \frac{1}{q(v,e)} \quad (4)$$

$$RLN = \frac{1}{k} \sum_e (\sum_v q(v,e))^2 \quad (5)$$

$$LGRE = \frac{1}{k} \sum_{v,e} \frac{q(v,e)}{v^2} \quad (6)$$

$$HGRE = \frac{1}{k} \sum_{v,e} v^2 q(v,e) \quad (7)$$

Where:

SRE: Is Short Run Emphasis which measures the distribution of short runs.

LRE: Is Long Run Emphasis which measures the distribution of long runs.

GLN: Is Gray Level Non-Uniformity which measures the distribution of runs over the gray values.

RPERC: Is Run Percentage which measures the fraction of the number of realized runs and the maximum number of potential runs.

LGRE: Is Low Gray Level Run Emphasis which measures the distribution of low grey-level runs.

RLN: Is Run Length Non-Uniformity which measures the distribution of runs over the run lengths.

HGRE: Is High Gray Level Run Emphasis which measures the distribution of high grey-level runs.

$q(v,e)$: Is the run length matrix.

v : Is the number of runs having pixels of gray level intensity.

e : Is the length of run on a specific orientation and k is the total number of runs.

First Order Histogram Based Features

To obtain various statistical properties first order histogram was used, it depends on individual pixel values to depict the region of interest (ROI).

In this technique, the intensity mean (IM), standard deviation (Stdv), the skewness (Skn), and the kurtosis (kt) can be extracted from the infected area since these features give a good indication of the distribution of intensity(15). As illustrated in the following equations:

$$IM = \frac{1}{N} * \sum_i \sum_j I(i, j) \quad (8)$$

$$Stdv = \sqrt{\frac{\sum_i \sum_j (I(i, j) - IM)^2}{N}} \quad (9)$$

$$Skn = \frac{1}{N} * \sqrt{\frac{\sum_i \sum_j (I(i, j) - IM)^3}{Stdv^3}} \quad (10)$$

$$Kt = \frac{1}{N} * \sqrt{\frac{\sum_i \sum_j (I(i, j) - IM)^4}{Stdv^4}} \quad (11)$$

Where:

IM: represent the mean.

Stdv: represent Standard Deviation.

SKn: represent Skweness.

Kt: represent Kurtosis.

I(i,j): represent the intensities of infected area and N the number of pixels in the infected area.

Neural Network Based on Scaled Conjugate Gradient (SCG-BP)

This learning algorithm with feed forward neural network is based upon a class of optimization techniques; well known in numerical analysis as "the Conjugate Gradient Methods" (16). SCG is fully-automated, includes no critical user-dependent parameters and avoids a time consuming line search. It is supervised learning algorithm with super linear convergence; super linear convergence is one advantage of utilizing this learning algorithm comparing with standard back-propagation and cascade neural network. SCG uses second order information from the neural network but requires only O(N) memory usage, where N is the number of weights in the network. The details of this training algorithm is described in(17).

Results and Discussions:

In this work, processor Intel (R) Core (TM) i7-2430M CPU @ 2.40GHz, RAM 4gb, 64 bit operating system, x64 based processor, R2016a matlab software and Windows 10 are used. Totally 120 colour potato images are used as image database with different background colour, potato images were captured using Sony Cyber-shot DSC-RX100 digital camera; The objective of presented PDCNN framework is to detect and classify four kinds of potato tubers diseases, the framework includes three levels. In the first level, K-means clustering algorithm is utilized to locate the infected area from the image then hybrid features have been extracted in second level. While in third level, the

FFNN based on (SCG-BP) learning algorithm is utilized for diseases classification process. In the sections below the implementation of each level.

Potato Diseases Detection Level

In this level, the K-means algorithm has been utilized to extract the infected area from potato image. The colored potato images of size (260 ×190) are fed in as a BMP image file; the image resolution is 24 bit/pixel. It is transformed to CIELAB color space (also known as L*a*b*); the K-means algorithm has been apply on transformed image to extract the infected area. Finally, the K infected area with different size are extracted. Due to this, the largest three or four infected portions are used in the next level, as illustrated in Fig. 5.

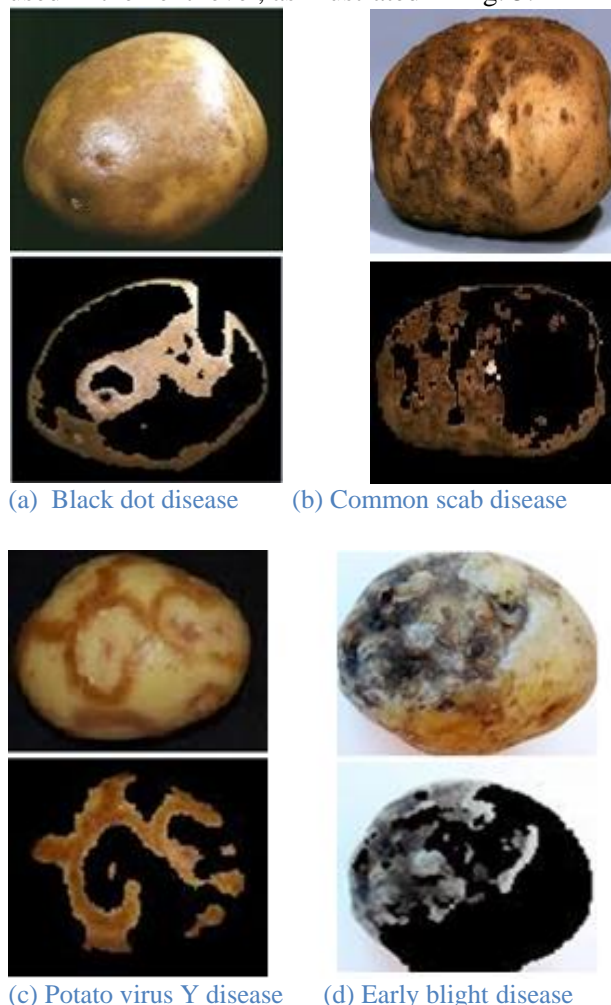


Figure 5. Four Types of Potato Diseases with its K Infected Area a) Image of black dot disease for potato; (b) Image of common scab disease for potato; (c) Image of virus Y disease for potato; (d) Image of early blight disease for potato.

Features Extraction Level

Significant characteristics will be extracted for the infected part. In given algorithm two type of hybrid features were extracted; (7) features of grey level run length matrix (GLRLM), with (4) features

of first order histogram. (11) attributes are taken out from disease area for next level.

Normalization and Classification Process Level

Two layer Feedforward Neural Network (FFNN) with Scaled Conjugate Gradient Backpropagation (SCG-BP) learning algorithm were utilized in this level. The weight and bias values were updates according to the Scaled Conjugate Gradient (SCG) method. The measure of error utilized in this work is cross entropy error (CE error). This learning algorithm is good choice for pattern recognition, its memory requirement is relatively small, and yet it is considerably faster than "standard gradient descent algorithms".

PotatoInputs matrix /PotatoTargets matrix; represents the Input/Target for the FFNN, the PotatoInputs matrix represents the features extracted from the potato images. 120 input images dataset of fresh potato were utilized, 80 samples used in training the network and 40 samples used for testing. Four kinds of potato diseases.; (11) features values extracted from each potato image for (120) images as explains in Fig.6. In the Targets matrix each column indicates a disease category with a one in either element 1, 2, 3 or 4 and zero for rest element as explain in Table 1.

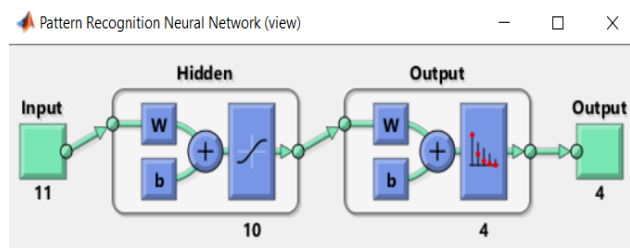


Figure 6. The FFNN of the presented PDCNN Framework

Scaling (normalization) of input matrix done using a min-max method as explained in equation (12).

$$X_i = \frac{(X_i - X_{Min})}{(X_{Max} - X_{Min})} * (b - a) + a \quad (12)$$

Where: X_i is the feature input values (1-11) and a, b are the scaling range.

X_{min} and X_{max} are values of the activated sigmoid functions dataset.

The FFNN utilized in this work was created and configured with sigmoid transfer function. The identification of training potato images achieved 100% rate. The rate of testing potato images set were achieved 91.3% when using 8 neuron in hidden layer. The default parameters of (SCG-BP) learning algorithm explain in Table 1, the targets matrix FFNN in Table 2, different number of hidden neurons were tried in this work as explain in Table 3. The results showed that the presented framework has given superior results compared with other works, it is considered the first work that classifies four kinds of potato tubers disease, most works in this field detected the potato leaves diseases and detected just one or two diseases. Each of evaluation procedure, performance and error histogram of the classification process are explained in Figs.7, 8 and 9.

Table 1. The default parameters of (SCG-BP) learning algorithm

Type of Potato Disease	Encoding for target matrix
Black dot	0001
Common scab	0010
potato virus Y	0100
Ring rot	1000

Table 2. The targets matrix FFNN

Number of hidden neurons	Training Correctly classified	Validation Correctly classified	Testing Correctly classified	Performance	Best Validation	Epoch iteration
6	100%	100%	89.2%	0.3379	0.36117 at Epoch 5	11
8	100%	100%	91.3%	0.2977	0.29154 at Epoch 17	23
10	100%	100%	90.3%	0.2978	0.31708 at Epoch 18	24
12	100%	100%	90.1%	0.2993	0.30726 at Epoch 15	21

Table 3. Training, validation and testing correct classify with 6, 8, 10, and 12 hidden neurons, total sample for each disease type is 30, 84 are training samples, 18 are validation samples, 18 are testing samples

SCG-BP parameters	default values
Maximum number of epochs	1000
Maximum validation failures	6
The change in weight for second derivative approximation	5.0e-5
Minimum performance gradient	1e-6

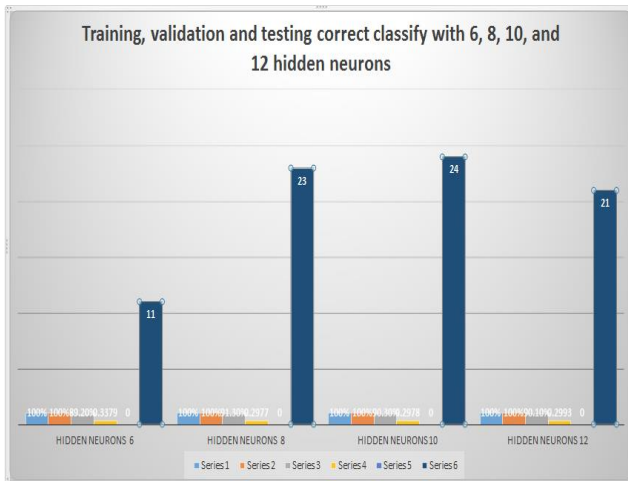


Figure 7. The Evaluation Procedure

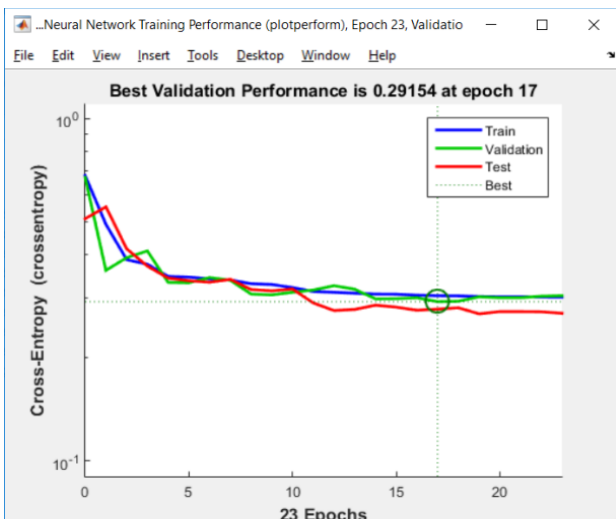


Figure 8. The Best Performance of FFNN

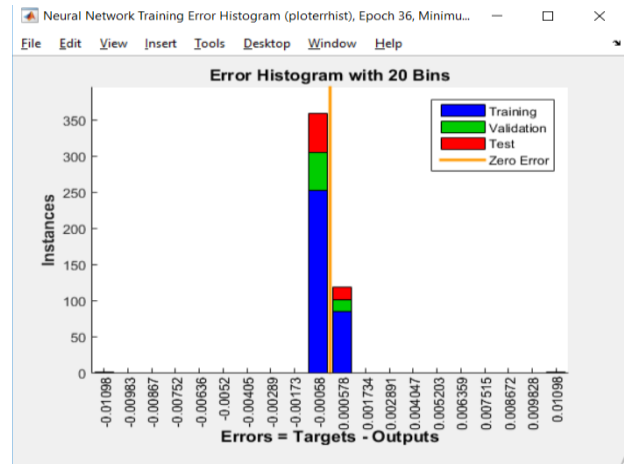


Figure 9. The Error Histogram of FFNN

Conclusion

In this paper, potato tubers diseases classification framework is proposed. Early detection and classification of potato diseases with this approach will reduce the large loss in agricultural crops. The images of the diseases are collected depending on the infected potato tubers which at first sight seem very similar and difficult to distinguish, this is a challenge, and the robustness in the proposed framework is its ability to effectively distinguish these diseases. The proposed framework consists of mainly three levels: pre-processing level, features extraction level and classification level. The K-means clustering algorithm was used to detect affected area, hybrid features were extracted then fed to FFNN. 120 potato images were utilized in this work, 80 of them for training phase and the rest 40 for testing, the proposed classification framework is qualified for classifying four kinds of potato tubers diseases with 91.3% of efficiency. In future work, we intend to develop a classification algorithm with an expanded number of potato tubers diseases classes.

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Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in AL-Mustansiriyah University.

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إطار عمل لتصنيف أمراض البطاطا بالاعتماد على الشبكة العصبية الأمامية

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الخلاصة:

يعتمد الاقتصاد بشكل استثنائي على الإنتاجية الزراعية. لذلك، في مجال الزراعة، يعد اكتشاف عدوى النبات مهمة حيوية لأنه يعطي تقدماً واعداداً نحو تطوير الزراعة. في هذا العمل، تم اقتراح نظام لتصنيف أمراض البطاطا بالاعتماد على الشبكة العصبية. يهدف النظام إلى كشف وتصنيف أربعة أنواع من أمراض درنات البطاطا وهي: النقطة السوداء، الجرب الشائع، فيروس البطاطا Y واللفحة المبكرة بالاعتماد على صورهم. يتكون النظام من ثلاثة مستويات: مستوى المعالجة المسبقة هو المستوى الأول، والذي يعتمد على K-means clustering لاكتشاف المنطقة المصابة من صورة البطاطا، المستوى الثاني هو مستوى استخراج الميزات والذي يستخرج الميزات من المنطقة المصابة بالاعتماد على طريقتين: length matrix grey level run و first order histogram based features. الميزات المستخرجة من المستوى الثاني تستخدم في المستوى الثالث في تغذية الشبكة العصبية الأمامية لإجراء عملية التصنيف. 120 صورة ملونة استخدمت، 80 صورة استخدمت في تدريب الشبكة و40 صورة استخدمت في عملية الاختبار. النظام المقترح فعال للغاية في تصنيف أربعة أنواع من أمراض درنات البطاطا وكانت نسبة التمييز 91,3 %.

الكلمات المفتاحية: ميزات المدرج الإحصائي من الدرجة الأولى، مصفوفة طول المدى للمستوى الرمادي، خوارزمية التجميع، أمراض البطاطا، خوارزمية مقياس الترافق التدرجي للانتشار العكسي.