Deep learning Neural Networks for the classification of potatoes from thermographs in big data

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Abstract

Quality assessment of potatoes is a major area of research in food industries. Major challenge in quality assessment of potato lies in the hidden disease which is invisible to the naked eye. Of the various Non-Destructive Testing (NDT) techniques, InfraRed Thermography (IRT) is used for acquiring thermal images of potatoes. Heat distribution analysis provides information about the type of abnormality in potatoes. Having acquired these thermographs, the next step is to store the thermal images. As large set of images are generated, these images are stored in the distributed file system. Features are extracted and are fed to classifiers. Initially Back Propagation Network (BPN) is used for classifying the potatoes. However, the proposed image segmentation technique could not isolate the fungi affected potatoes. Hence in this work, deep learning neural network which accepts the input as images and provides automated classification without abnormality isolation. Accuracy of detection is 100% for normal, fungi affected potatoes and severely affected potatoes in CNN. Images are retrieved from DFS and and features are extracted and fed to classifiers

Keywords: Potatoes, normal, fungi, thermographs, Back propagation Network, Alexnet

1. Introduction

Potato is one of the most important vegetables which are exported to foreign countries. However quality assessment of potato is the most important challenge in our country. Potato is one such vegetable where the abnormality is not visible to naked eye. Hence it needs an assessment technique that involves a sensor which is capable of showing the abnormality. All the objects above 0 Kelvin emit heat and the emitted heat is dependent on the nature/characteristics of the specimen. In a potato, temperature of the abnormal region is different from that of the normal region. Hence heat can be used as effective measure for characterizing the abnormality. Also, the proposed technique must be non-destructive, non-contact and non hazardous in nature. InfraRed Thermography is one such technique that uses and IR camera to capture the heat pattern. These heat patterns are then converted into thermographs. These thermographs are then analyzed for assessing the quality of potatoes. Automated analysis of tehrmographs involves thermograph acquisition, storage, feature extraction and classification.

Considerable research work is carried out in this area. Peng Guozhao and Luo Qing (2010) studied the impact of climatic conditions on the development of late blight in potatoes. In this work, Back Propagation Network is used for forecasting the occurrence of late blight defect in potatoes. Lingjie Yao et al (2017) used integrated color model for the detection of green skin in potatoes. Initially potatoes are acquired with visible light, color, RGB and HSV features were extracted and decision is made. Selvarasu et al (2007) used InfraRed Thermography for abnormality detection in human. Sangeetha and Nandhitha (2018) used InfraRed Therrmography for the condition monitoring of electrical equipment. Selvarasu et al (2010) proposed histogram and wavelet features for the classification of abnormality from breast thermographs. However, the accuracy of classification has to be further improved. Hence in this work, automated classification of potatoes from thermographs is developed with conventional Back Propagation Network (BPN) and Convolutional Neural Network (CNN).

Thermograph database is explained in Section 2. Conventional and proposed neural network-based classification of potatoes are explained in section 3 and 4 respectively. Conclusion and future work are listed in Section 5.

2. Thermograph database

Conventional image processing algorithms do not work for thermographs. Hence thermograph specific image processing technique has to be developed. Thermal images of potatoes are obtained using SCT-460 thermal camera. Four different types of potatoes namely normal potatoes, fungal infected potatoes, potatoes with visible holes and potatoes which are severely damaged are considered to create the thermal database (Table 1). These images are stored in Distributed File System (DFS).

Potatoes	No. of thermographs
Normal potatoes	16
Fungi affected potatoes	12
Potatoes with holes	14
Severely affected potatoes	17

Thermographs of normal potatoes, fungi affected potatoes, potatoes with visible holes and worst affected potatoes are shown in Figures 1-4.

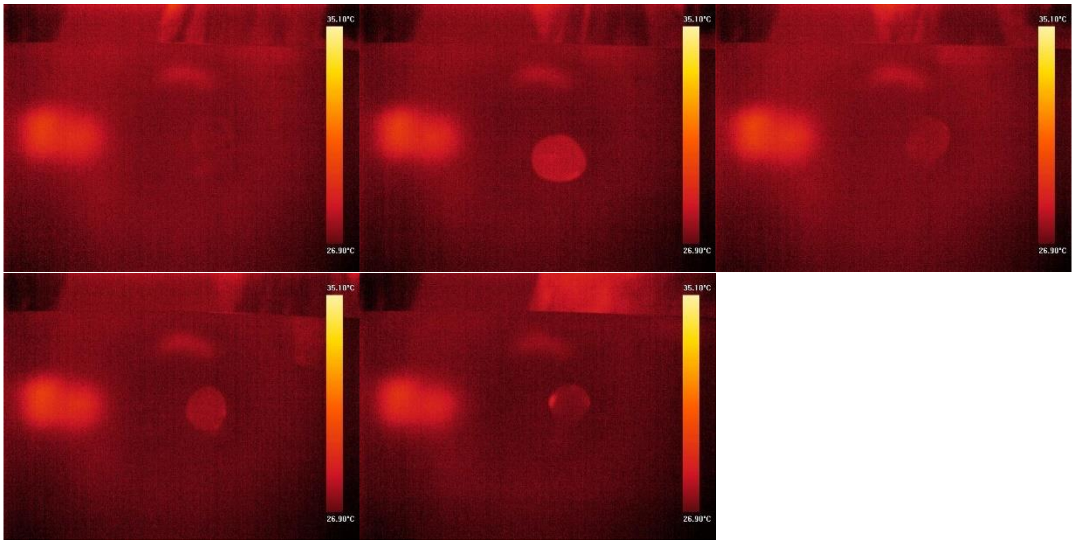


Figure 1 Thermographs of normal potatoes

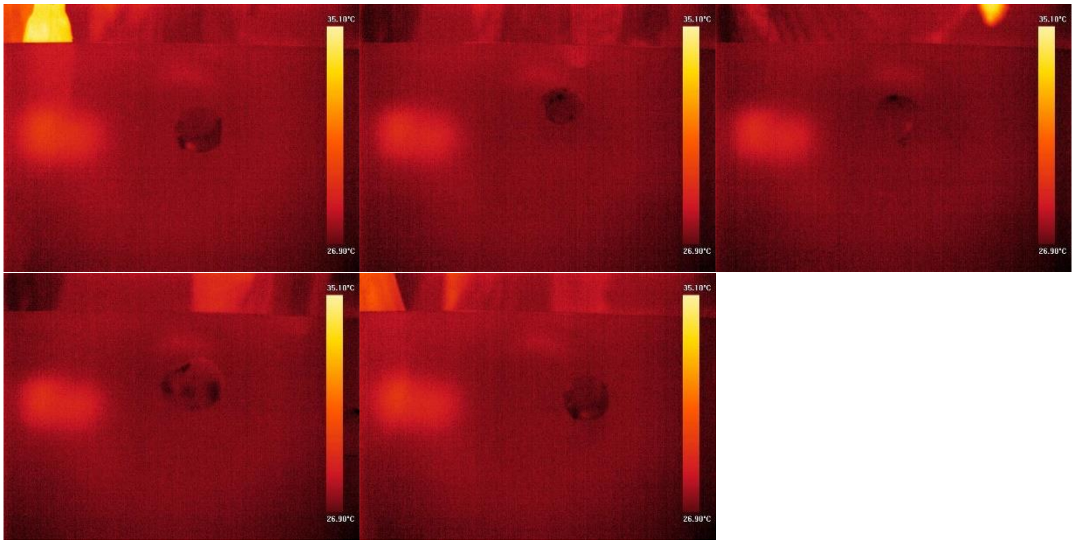


Figure 2 Thermographs of fungi affected potatoes

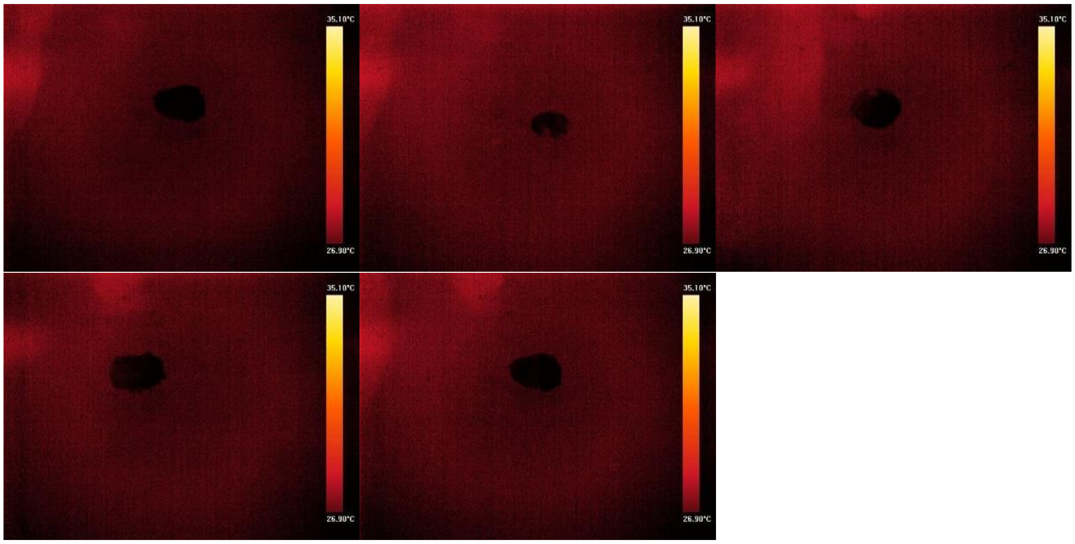


Figure 3 Thermographs of potatoes with holes

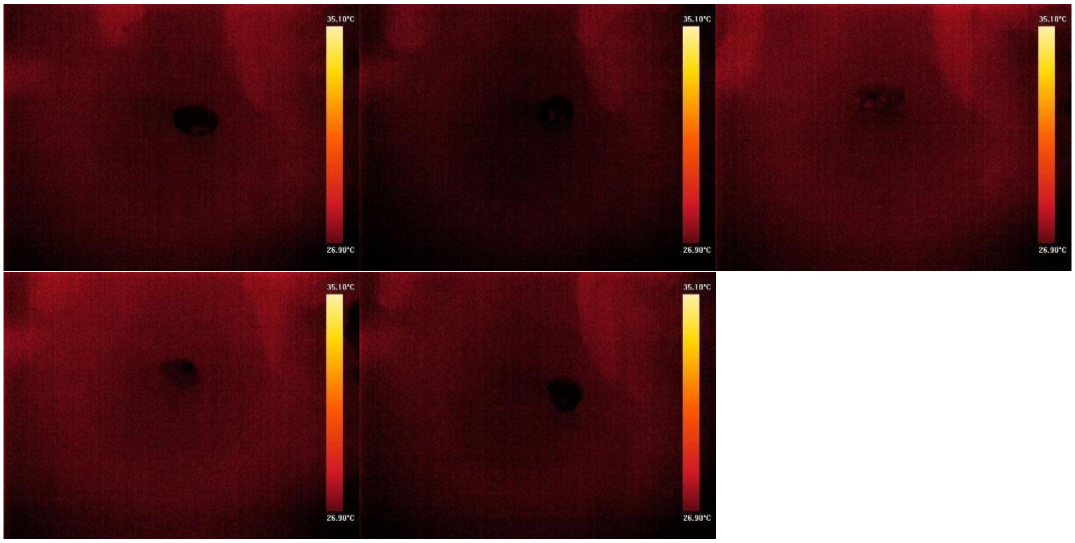
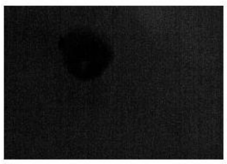
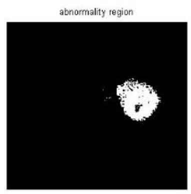


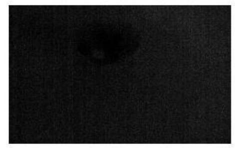
Figure 4 Thermographs of severely affected potatoes

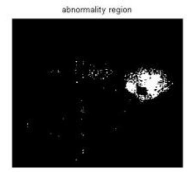
3. BPN BASED CLASSIFICATION

Pseudo color thermographs are converted into gray scale and image complement is performed on these images. In order to extract the features, region of interest has to be isolated. Of the various image segmentation techniques, region growing is used for extracting the region of interest. Seed pixel intensity and threshold for the entire set of thermographs is 19 and 16 respectively. Dissimilarity index is calculated by finding Euclidean distance between the seed pixel intensity and every other pixel in the gray scale thermograph. If the distance is less than the threshold then the pixels are retained (Region of Interest). Else intensity of the background pixels is made zero. Gray scale image and the output images are shown in Figures 5, 6, 7 and 8 respectively.









From subjective analysis, it is visible that potato is identified to its true size in the output images. If potato is normal, then the size of the region of interest is larger than that of the affected potatoes. After identifying the abnormality, it is represented with image features. In this work, area, filled area, convex area, major axis length and minor axis length are used for characterising the abnormality. These features provide the dimensions of the abnormality. These features are then used for generating the exemplars (Table 2). Numerals 1, 2 and 3 are used for coding severely affected potatoes, normal potatoes and potatoes affected by holes.

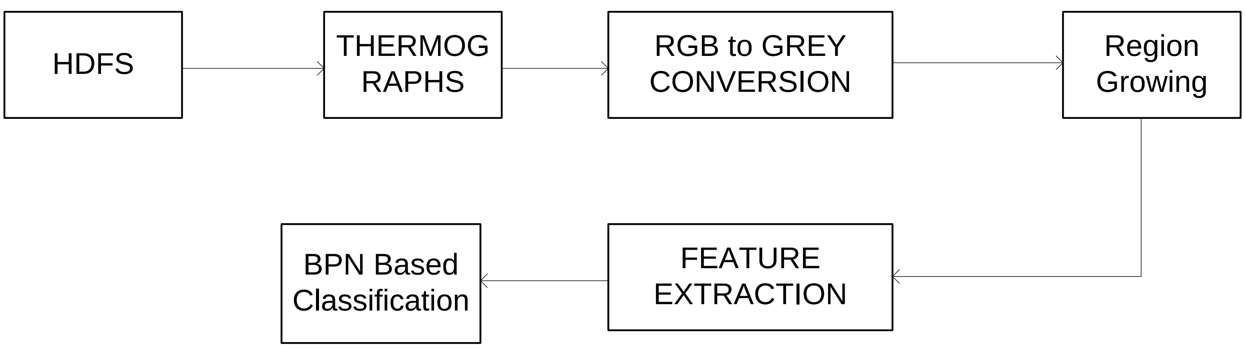


Figure.6.BPN based classification of Potatoes

Table 2 Exemplar generation for training and testing Back Propagation Network

Convex area	Filled area	Area	Major axis length	Minor axis length	Type
1195	913	780	41.9519	32.0494	1
3	3	3	2.582	1.7638	1
2	2	2	2.3094	1.147	1
61	49	49	10.57097	6.665637	1

45540	38641	27164	296.2469	187.4615	2
3037	2464	2199	68.10698	48.44064	3
2	2	2	3.05505	1.154701	3
4513	4050	3711	92.02754	59.06359	3
4	4	4	4.618802	1.154701	3
3	3	3	2.581989	1.763834	3
4426	3843	3721	81.8557	62.86018	3

Block diagram in Figure 6 summarizes the steps involved in this work. Images are extracted from distributed system, image segmentation using region growing, feature extraction, exemplar generation, training, testing and implementing the neural network. In this work, a five layered neural network with one input layer, three hidden layers and one output layer is used. Specification of BPN is shown in Table 3. Three different neural networks are created with 10,5,2, 5,2,2 and 20,10,5 neurons in the hidden layers.Two different sets of data are used for testing and training. 27 exemplars are used for training while remaining 20 exemplars are used for testing.

Table 3 Specifications of the proposed BPN

Parameters	Values
Number of neurons in input layer	5
Number of hidden layers	3
Activation function (hidden layer)	Tansigmoidal
Activation function (output layer)	Purelinear
Learning parameter	0.6
Momentum parameter	0.9

Relationship between desired output and the actual output for the three different architectures are shown in Table 4. From the Table 4 and Figure 5, it is evident that BPN architecture with 10, 5, 2 neurons outperform the other two networks. Performance is also measured in terms of probability of detection for three different architectures as shown in Table 5.

Table 4 Impact of hidden layer neurons on the classification of thermographs

Desired output	Actual output		
	10, 5, 2	5, 2, 2	20, 10, 5

1	1	1	2
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	2
1	1	1	1
1	2	2	2
1	1	1	2
1	1	1	2
1	1	1	2
1	1	2	1
2	2	3	2
3	3	3	3
3	3	3	2
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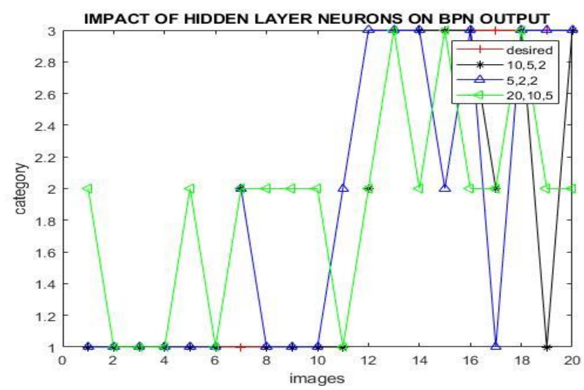
3	3	3	3
3	1	3	2
3	3	3	2



.Figure 7 Impact of hidden layers on the performance of the BPN

From the Table 5, it is found that Back Propagation Network with 10, 5 and 2 hidden layers work well for the classification of all the three classes with an accuracy of detection as 100% (normal), 75% (potato with holes) and 90% (severely affected) respectively. On the other hand, BPN with 5,2 and 2 neurons classify with an accuracy of 100%, 75% and 81% for normal potatoes, potato with holes and severely affected potatoes respectively. An accuracy of 33% (potato with holes) is obtained for BPN with 20, 10 and 5 hidden layer neurons. Of all the three architectures, the best result is obtained for BPN with 10, 5 and 2 hidden layer neurons because of the optimized number of neurons in each case.

Table 5 Probability of Detection

Abnormality	Normal			Holes			Severely affected			Accuracy		
	10, 5, 2	**5, 2, 2**	**20, 10, 5**	10, 5, 2	**5, 2, 2**	**20, 10, 5**	10, 5, 2	**5, 2, 2**	**20, 10, 5**	10, 5, 2	**5, 2, 2**	**20, 10, 5**
Normal	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**100%**	**100%**	**100%**
Holes	**1**	**1**	**5**	**6**	**6**	**3**	**1**	**1**	**0**	**75%**	**75%**	**33%**
Severely affected	**1**	**2**	**6**	**0**	**0**	**0**	**10**	**9**	**5**	**90%**	**81%**	**50%**

However the proposed region growing technique could not provide the exact isolation of potatoes which are affected by fungi. Though, the above feature extraction and classification technique was developed for classifying four types of potatoes, the proposed technique is used for classifying only three classes of potatoes. Also the performance of the proposed technique is strongly dependent on the features representing the Region of Interest.

4. ALEXNET FOR CLASSIFICATION OF POTATOES

In order to improve the performance of the classification technique, directly thermographs are to be fed as inputs to the classifier. Such a neural network is Alexnet which determines the features on its own and also performs classification. The only limitation in using Alexnet is that the input images must be resized to 256x256. Alexnet consists of a total of 8 layers where the first five layers are convolutional and the last three layers are fully connected. Alexnet uses Rectified Linear Unit (ReLU). Similar to BPN, it uses 'hyperbolic tan' or 'sigmoidal' function. The block diagram for alexnet based classifier is shown in figure 7. Four classes are coded as t1, t2, t3 and t4 for normal potatoes, fungi affected potatoes, potatoes with holes and severely affected potatoes. Probability of Detection is as shown in Table 6.

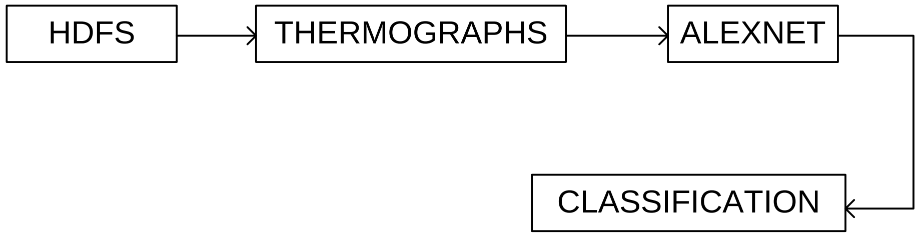


Figure.7 CNN based classification of Potatoes

Table 6 Probability of Detection from Alexnet

Classes	Normal	Fungi affected potatoes	Potatoes with holes	Severely affected potatoes	Accuracy
Normal	4	0	0	0	100%
Fungi affected potatoes	0	4	0	0	100%
Potatoes with holes	1	0	4	0	80%
Severely affected potatoes	0	0	0	5	100%

From Table 6, the proposed Alexnet works well for normal, fungi affected potatoes and severely affected potatoes with 100%. Accuracy of prediction for potatoes with holes is also 80%.

5. CONCLUSION AND FUTURE WORK

Two different classification techniques for automated classification of potatoes from thermal images is developed. The first technique is the conventional approach, where the potatoes are isolated from background and the features representing the size of the potatoes are used for training and testing Back Propagation Network. Of the three different hidden layer architectures, it is found that 10, 5 and 2 neurons each in the hidden layers provides the best classification. However the above technique cannot be used for the classification of fungi affected potatoes as the Region of Interest could not be isolated. Hence Convolutional Neural Network with 8 layers called Alexnet is used for training and testing. Performance of Alexnet is much better than conventional neural network for all the four classes. The major advantage of Alexnet is that it itself extracts the features and uses it for classification. However the work has stopped at the simulation itself. Also potato images are obtained from DFS of only one system. In future, images can be obtained from a cluster of networks. FPGA implementation of the proposed classification technique can be done in future.

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