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Research Article

Internet of Things-Based Crop Classification Model Using Deep Learning for Indirect Solar Drying

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The energy which is obtained from the sun in the form of light and heat is known as solar energy. Nowadays, technology is focused on utilization of this rich resource of energy. So many ways to harness and utilize this source of energy have already been introduced; solar drying of crops is one of its applications. Drying of crops is required to improve the quality of the crops as well as to protect crops from so many unwanted issues like moisture, pest/insect attacks, and birds/animals. Traditional methods are still used to dry the crops; drying of crops is required to preserving food product for long time. In this paper, we studied about the working mechanism of indirect solar dryers and introduced IoT-based system to control and monitor the temperature of the solar dryer as per the requirement of specific crop. To achieve the automation accurately and precisely deep learning method is also used to set the required temperature according to the requirement of the specific crop.

1. Introduction

The devices having combination of hardware and software are known as embedded systems; and such devices are having capabilities of communicating and establishing connections with similar kind of devices via Internet, then these devices become Internet of Things [1], where things are nothing but the embedded systems or nodes [2]. Internet of Things is contributing in each and every sector nowadays such as healthcare [3], industries, home appliances, and agriculture [4–6]. Among the overall production of the food materials around the world end up with half of its production gets wasted or rotten, due to so many factors affecting the crop during the postharvest management of the crop, such as contamination and pest, birds, and animal attacks; each crop has its own ability of hold and its strength against the contamination. Fruit crops with pulp content are more prone to get rotten in very less time [7]. We can stop these loses with the use of Internet of Things. Internet of Things in agroindustry gives rise to the more accurate production [8]. Internet of Things can play a vital role in the fulfillment of the requirement of the food products for the world [9]. The deployment of the various sensors like soil moisture, temperature, pH, and NPK sensors helps farmers to analyze their crops in better way with detailed data of the particular crop [10]. The data provided by these agriculture of things devices not only helps to analyze the status of the

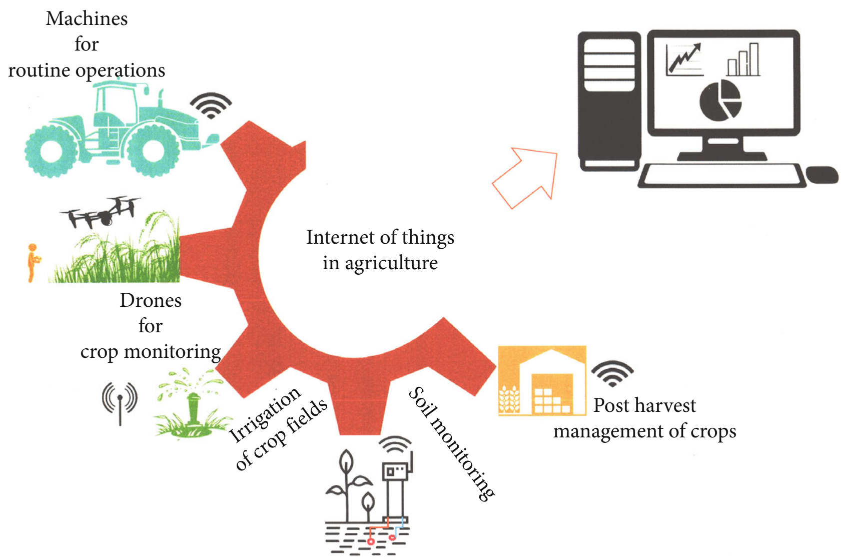

FIGURE 1: IoT providing numerous services in different sectors of the agriculture industries.

crop parameters but also allows us to maintain and store these crops for longer time period after harvesting [11, 12]. Figure 1 illustrates the role of IoT providing assorted services in different sectors of the agriculture industries.

According to the requirement of agroindustry, different types of dryers are available based on various sizes and designs [13]. These dryers can be classified based on solar power, movement of air, the direction of air, kind of insulation provided, and which type of products are used for drying [14, 15]. There are two major categories: (A) passive mode and (B) active mode; then, these two major categories have further subcategories which are (1) direct solar dryer, (2) indirect solar dryer, and (3) mixed-mode type solar dryers. The conventional method of drying to preserve grains, vegetables, and fruits for a long time is sun-drying which is a free source of renewable energy [16]. For large-scale production, this method has various limitations of drying like damage to the crop from various birds, rats, and animals. The quality of the crops also gets degraded due to the direct exposer to sun radiation. Moreover, contamination can also occur due to so many factors due, rain, dirt, and dust.

If drying of agricultural products is done with controlled and specific temperature. Then, the outcome of the process can allow us to dry the product rapidly to the safe exact moisture content required by the product with superior quality [17]. The required amount of temperature of hot air which will be circulated through the crop chamber depends on the compassion of product. Various solar dryers have been designed and implemented in the last one decade. But all are mechanical and manually used solar dryers [18]. On the other hand, artificial intelligence and Internet of Things are proving their worth in almost every sector, as solar dryers play very vital role in postharvest management of crops [19]. The solar dryers that are still in use come with basic applications like the temperatures which are required

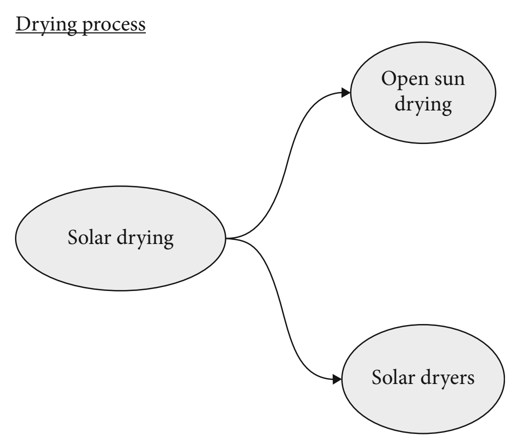

FIGURE 2: Drying process of the crops.

for the crops that can be kept only within the ranges like 45 to 75°C. The dryers available in the market cannot provide ease of use as the temperature required for the vegetables and fruits is different, and it is maintained manually; so, it needs to be upgraded according to the requirement of the needs.

The automation of the dryer can easily be achieved by developing an IoT-based system with the help of Arduino and Raspberry Pi, microcontrollers, and microprocessors [20]; to give more accuracy and effectiveness, deep learning method is used [21, 22]. This paper majorly focuses on two aspects to provide user a product with precise and exact system to control the drying of crops and fruits: (1) IoT-based automation of the solar dryer; (2) crop classification methods using deep learning.

1.1. Problems Addressed in This Paper

(1) To provide an IoT-based system for the automation of the indirect solar dryer

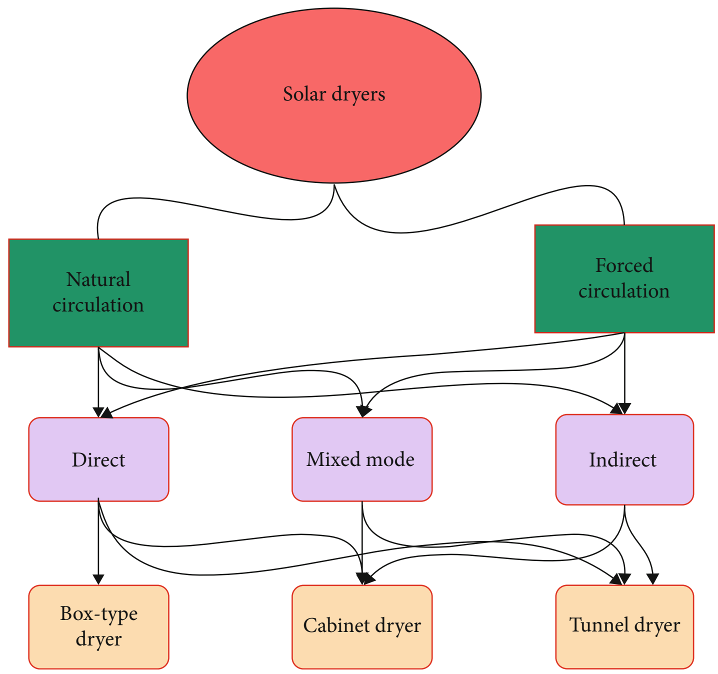

Figure 3: Classification of dryers.

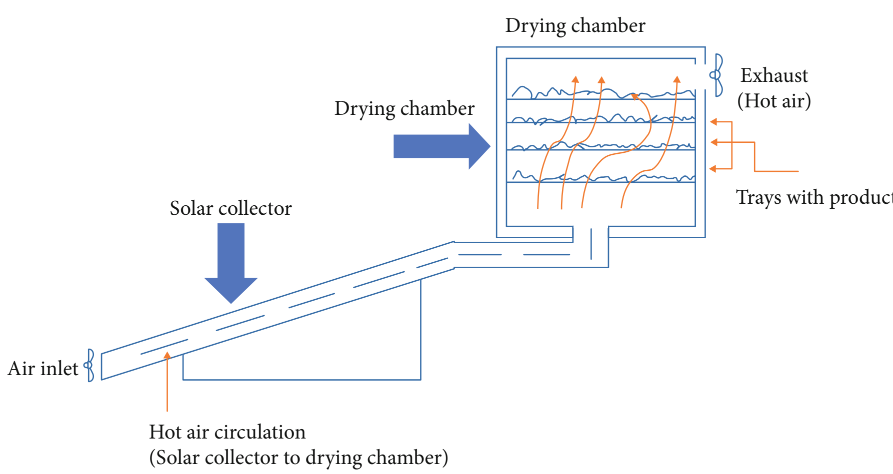

Figure 4: General working of the indirect solar dryer.

(2) To introduce deep learning method for the crop classification

By introducing these two goals to the existing system, the manual dryers can be replaced with the fully automatic and self-driven systems with capabilities of ease of use and specific operation according to the crops.

2. Background Study

Drying of crops is always considered as an energy-intensive and cost-effective method to increase the storability of several crops. The reduction of the moisture content from the crop prevents the risk of microorganism growth and minimizes many of the reactions like nonenzymatic browning, enzymatic reactions, oxidations of lipids and pigments and substantially reduces the weight and volume [23].

In the last decade, distinct types of dryers have been introduced to reduce the postharvest losses and hence to increase the productivity and product quality of the crops. However, on the implementation of these introduced solar dryers, only few of them have reached to the scale level and have been commercialized. Figure 2 illustrates the techniques used for crop drying process.

Table 1: performance of indirect solar dyer for various crops.

Mass of the product	Reduced to	Moisture content	Final moisture content	Crop	Reference
2 kg	.5628 kg	356%	16.3292% 19.4736% 21.1592% 31.1582% 42.37% (open sun drying)	Banana	[16]
1.8 kg	0.14 kg	93%	10%	Tomato	[25]
.8864 kg	***	86%	8.12%	Apple	[26]
1 kg	***	83%	12%	Papad	[27]
***	***	77.75%	14.53%	Grapes	[28]
2 kg	***	78%	18.05%	Banana	[16]
7.45 kg	***	93.81%	6.54%	Tomato	[29]
10 kg	***	80%	18%	Grapes	[30]
10 kg	***	80%	13%	Apricots	[30]
50 kg	***	60%	12%	Silk cocoon	[31]
***	***	77.2%	34.98%	Banana	[32]
38.4 kg	***	90.21%	10%	Red chili	[33]
40 kg	***	80%	10%	Red chili	[34]

Table 2: Efficiency and temperature used for drying crops in indirect solar dryers.

Temp (collector)	Drying outlet	Thermal collector efficiency	Drying efficiency
81 (no load condition) 38 to 81 (with load condition)	78	31.50%	22.38% [16]
50 to 62 and 23 to 32	45	30%	17% [25]
20.5 to 34.0	25.5 to 47.5	***	17.89% [26]
***	65	49.45%	4.12% [27]
***	51.9-64.6	48-56%	*** [28]
***	62	49.45%	4.12% [16]
***	62	55.45%	8.8% [29]
20	***	65%	*** [30]
33	***	60%	*** [30]
50-75	***	***	8.8-9.2% [31]
45	***	29.63%	4.96% [32]
51.89	***	61.62%	24.04% [33]
57	***	28%	13% [34]

Table 3: Maximum temperature allowed for the specific crop [35].

Sr. no.	Crop	Max temperature allowed in °C	Reference
1.	Apple	65-70	
2.	Apricots	65	
3.	Bananas	70	
4.	Cabbage	55	
5.	Carrot	75	
6.	Cauliflower	65	
7.	Figs	70	
8.	Garlic	55	
9.	Green beans	75	[35]
10.	Guava	65	
11.	Maize	60	
12.	Onion	55	
13.	Peaches	65	
14.	Potato	75	
15.	Rice	50	
16.	Sweet potato	55	
17.	Tomatoes	60	
18.	Wheat	45	

In solar dryers, the crops are not exposed directly to the radiation, while, in open sun drying, the crops are exposed to the direct sun radiation which makes crops more prone to the various issues such as contamination, pest, birds, and animal attacks. Solar dryers can be classified as natural circulation and forced circulation. Figure 3 illustrates the classification of solar dryers.

Goyal and Tiwari [24] proposed a system and analyzed the performance of RACD (reverse absorber cabinet dryer). Indirect solar dryer is formed of two major blocks, i.e., solar collector and drying chamber. The drying chamber is used for keeping all the crops on a wire-mesh trays; number of trays can depend on the overall weight ability

Table 4: The average price of crop sold in Solan Mandi.

Sr. no.	Crop	Price per kg (average in 2020) Min Price/kg (Avg) INR	Max Price/kg (Avg) INR	Reference
1.	Apple	15/-	34/-	[36]
2.	Apricots	16/-	29/-	
3.	Bananas	11/-	26/-	
4.	Cabbage	12/-	15/-	
5.	Carrot	17/-	22/-	
6.	Cauliflower	14/-	20/-	
7.	Garlic	70/-	121/-	
8.	Guava	19/-	29/-	
9.	Onion	23/-	28/-	
10.	Peaches	20/-	28/-	
11.	Potato	17/-	24/-	
12.	Tomatoes	11/-	26/-	

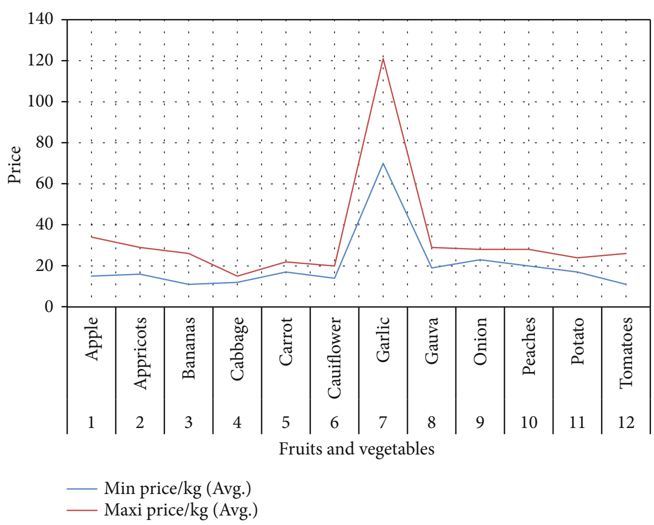

Figure 5: Graphical representation of difference in between min and max price.

and size of the dryer. All crops that are going to be dried will be placed on these wire-mesh trays. In solar collector chamber, it is made of absorbing materials like aluminium plates, river rocks, and black paint coating. These types of materials help the solar collector to absorb the sun radiation and hence rise in solar collector as the chamber is air-tight closed using a glass. Air is circulated to this chamber with the help of two intake dc fans. This circulated air then comes in contact with the raised temperature, and hence, the temperature of the circulated air also increases. Warm air is then circulated to the drying chamber where crops are placed on wire-mesh plates.

Figure 4 illustrates the general working of the indirect type of solar dryer.

Table 5: Average price of the dried crop.

Sr. no.	Dried crops	Price in INR of dried powder per kg	Reference
1.	Apple (powder)	2610/-	[37]
2.	Apricots	699/-	
3.	Bananas (chips)	535/-	
4.	Cabbage	2439/-	
5.	Carrot	2439/-	
6.	Figs	1070/-	
7.	Garlic (powder)	1250/-	
8.	Green beans	3160/-	
9.	Guava (powder)	2780/-	
10.	Onion	2529/-	
11.	Peaches (slices)	1484/-	
12.	Potato (dices)	840/-	
13.	Tomatoes (powder)	1023/-	

Drying of the crops works due to the differences in moisture concentration between the air (drying) and the air (vicinity) of crops surfaces.

Tables 1 and 2 provide the key findings of various research article published across the globe focusing on the research area of solar dryers.

Indirect solar dryers are providing better solution of drying the crop, but further improvements and technological advancements are required, like fully automatic systems are not available; from the above literature survey, we found that crops require specific temperature to be maintained for best results. Table 3 represents the data of temperature required for the drying of specific crop [35].

3. Materials and Methods

Internet of Things is playing crucial role in advancement of many sectors. Agriculture sector is the one sector which requires so many advancements, especially in case of countries like India. Farmers in India still uses traditional methods of agriculture; IoT can play vital role for the development of India's economy also as it holds around 14% share in Indian economy and around 42% of total employment. Table 4 shows the average price of crop per kg sold by the farmer to Solan Mandi in the year of 2020, whereas Figure 5 illustrates the graphical representation of minimum and maximum price variation of a specific crop sold at Solan Mandi during the season of a crop. Only for Apricots, we took the data for 2019; as for 2020, it was not available; data is collected using the Govt. of India website, whereas in Table 5, we have given the price of dried crop, and Figure 6 illustrates the graphical representation of the comparison of prices in between dried and normal crops.

3.1. Implementation. The entire system is implemented, for the construction of major body of the solar dyer plyboard

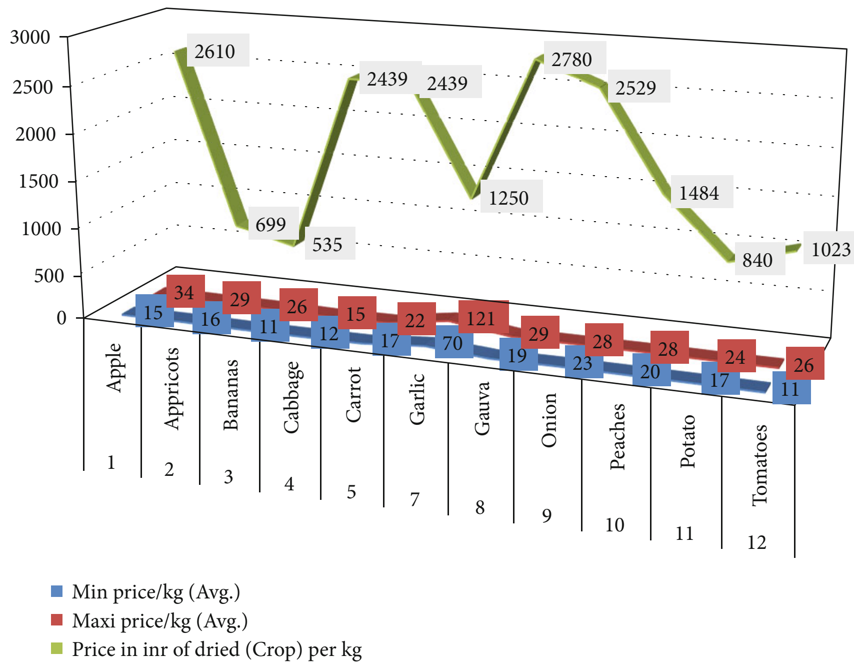

FIGURE 6: Price comparison of crops, dried/normal.

FIGURE 7: Front view.

FIGURE 8: Left side view.

is used; the whole dryer system, i.e., drying chamber and solar collector unit, is placed on the stand made up of iron rods, to absorb the sun radiation small pieces of river stones and pieces of iron; aluminium sheet coated with black paint has been used. Figures 7 and 8 illustrate the development stages of the implemented system.

3.2. IoT-Based System. Internet of Things is playing crucial role in advancement of many sectors. Agriculture sector is the one sector which requires so many advancements, especially in case of countries like India. Farmers in India still uses traditional methods of agriculture; IoT can play vital role for the development of India's economy also as it holds around 14% share in Indian economy and around 42% of total employment. The proposed system provides solution for the agroindustries and agribusiness, to maintain the crops after postharvest. Raspberry Pi is used to develop the system. Figure 9 illustrates the flow diagram of whole solar dryer, and Figure 10 illustrates the circuit diagram of the system developed.

The developed system is placed inside the drying chamber. Crops will be identified by the camera. Components used for the development are as follows:

(1) Raspberry Pi

(2) 5 MP Omni-vision 5647 Camera Module

(3) DHT22 temperature and humidity sensor

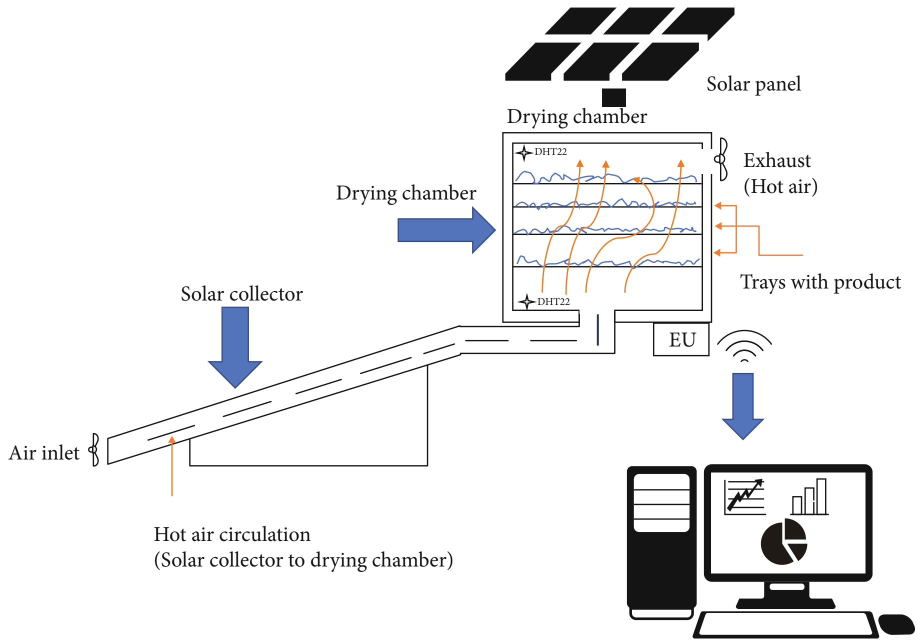

Figure 9: Working of proposed system.

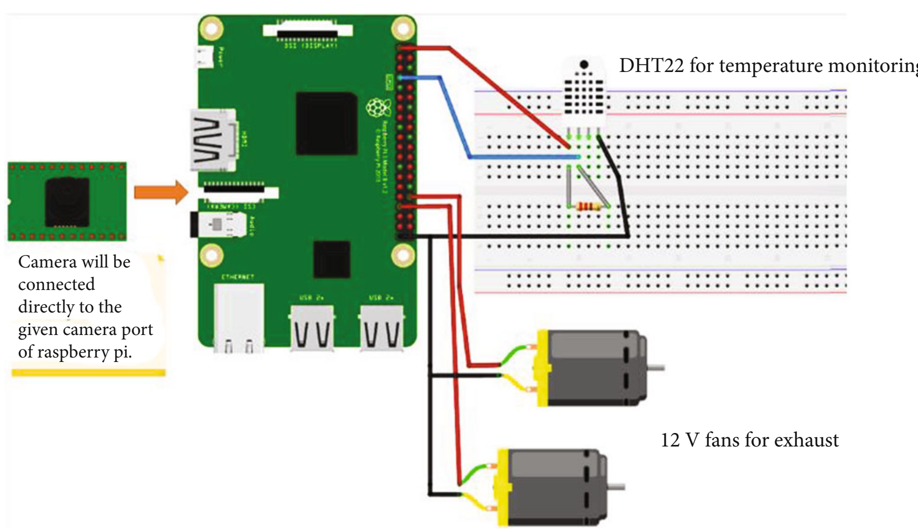

Figure 10: Circuit diagram for identifying crop in drying chamber.

(4) 12 V DC fans as exhaust

(5) Battery 12 V

The system is trained for the detection of the specific crop and the value of temperature required for the drying of the crop. Once the crop is placed inside the drying chamber, it will automatically set the limits of the temperature to the required amount. User can observe the process using the UI; for this proposed system, we have used Adafruit and developed a dashboard for the observations. Same has been discussed in the result section.

3.3. Deep Learning Method for the Crop Classification. There are many machine learning algorithm/classifiers used in crop classification starting from SVM, Random forest, linear and logistic regression, KNN, PCA, and more, all are achieving accuracies in between 90 and 96%, respectively [38]. All these classifiers are comprise of the following limitation.

(1) The classifier may not be strong because different fruits may have analogous or indistinguishable features in relation to shape and color

(2) Certain detection techniques are unable to categorize entire crop varieties; these techniques can categorize similar class only

(3) Detection method requires additional devices for crop image classification

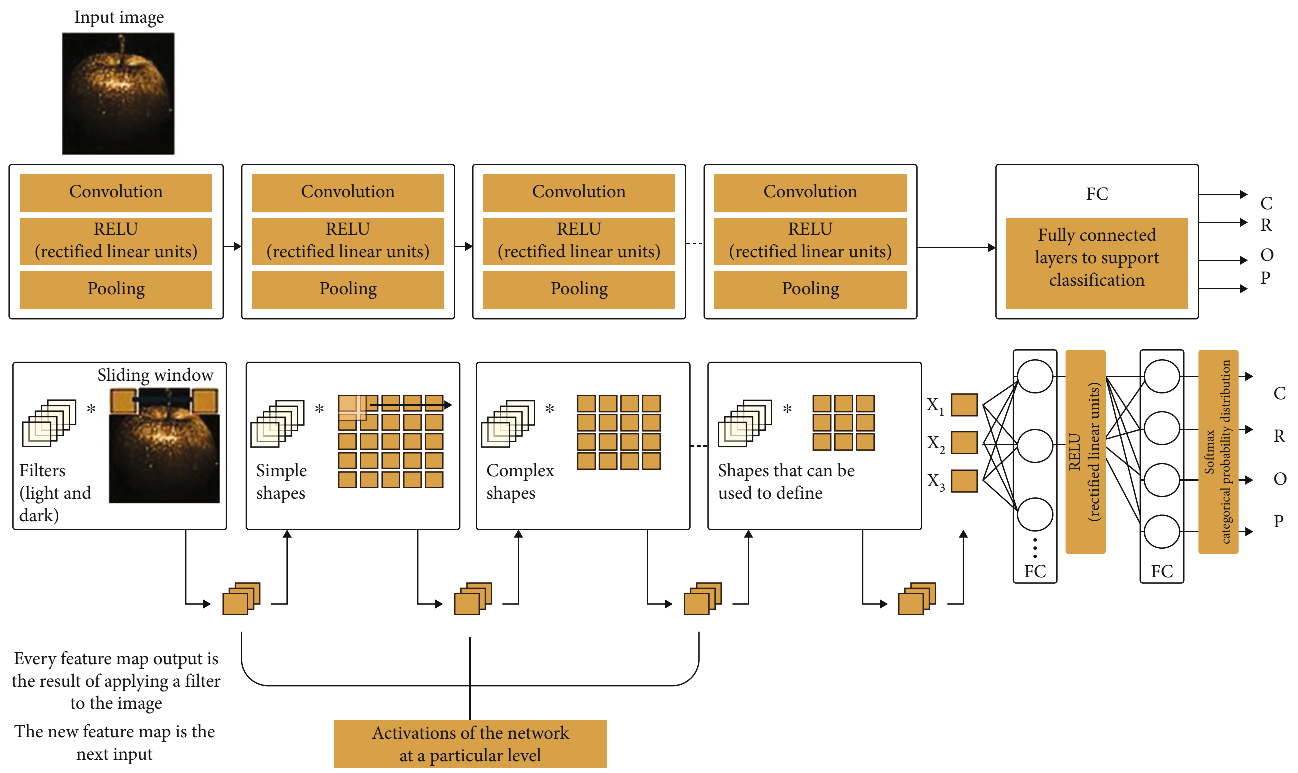

Figure 11: Classification of crop using CNN architecture.

Table 6: The hyperparameters and other variables.

Sr. no.	Layers	Number of layers	Range
1	Conv2D	4	224-2320
2	Activation function (ReLu)	5	
3	Activation function (SoftMax)	1	
4	MaxPooling2D	2	(2,2)
5	Dropout	3	0.25
6	Flatten	2	0, 40000
7	Dense	1	23, 5097
Learning rate 0.001			
Epoch 0-60			

(4) These classifiers are not used in accordance with indirect solar dryer

To conquer these limitations mentioned above, in this manuscript, we give an effective DL approach for crop image categorization. Our approach is centered on the CNN and comprises multilayered feedforward neural networks which learn task features in a categorized way. Figure 11 illustrates the classification model of crops.

The proposed approach precludes the challenges of other superficial-learning-based methodologies. Furthermore, there is a requirement of immense, labelled dataset to match DL models, resolved with transfer as well as reinforcement techniques. The proposed approach examines two unique deep-learning architectures. The anticipated approach practically overpowers the limitations mentioned above.

The proposed approach is divided into three subparts: first part is preprocessing; here, we shorn the picture into equal size; afterwards, all are resized, as an initial response to the model. In the second part, feature conversion step was accomplished via recurring pooling as well as convolution functions. As shown in the figure, it consists of four successive sections pursued by a fully connected layer. Every section consists of 2 consecutive conv layers followed with pooling layer (max pooling). The layer in the proposed approach uses ReLU as initiation function, easiest nonlinear function, as shown in equation.

The hyperparameters and other variables used in crop classification are mentioned in Table 6; in Table 7, details of usage of layer for crop classification model are given.

In the proposed approach, we used kernel size for CNN and for maxpooling. The stuffed convolutional layers characterize the input image at various levels of extraction. The decisive phase is the categorization; the features mapped, which are studied in the preceding step, are compressed into a feature vector, which are then supplied to decisive layer. The decisive is the entirely linked layer of nerve cell with the classes in equal number. The activation function, i.e., SoftMax, is used in output layer; here, we need to get the output of classes in probabilistic manner.

Table 7: The detailed usage of layers in crop classification along with their output shape and param.

Sr. no.	Layers	Output shape	Param
1	Conv2d (Conv2D)	(None, 200, 200, 8)	224
2	Activation (ReLu)	(None, 200, 200, 8)	0
3	Conv2d_1 (Conv2D)	(None, 200, 200, 8)	84
4	Activation_1 (ReLu)	(None, 200, 200, 8)	0
5	Max_pooling2d (MaxPooling2D)	(None, 100, 100, 8)	0
6	Dropout (dropout)	(None, 100, 100, 8)	0
7	Conv2d_2 (Conv2D)	(None, 100, 100, 16)	1168
8	Activation_2 (ReLu)	(None, 100, 100, 16)	0
9	Conv2d_3 (Conv2D)	(None, 100, 100, 16)	2320
10	Activation_3 (ReLu)	(None, 100, 100, 16)	0
11	Max_pooling2d_1 (MaxPooling2D)	(None, 50, 50, 16)	0
12	Dropout_1 (dropout)	(None, 50, 50, 16)	0
13	Flatten (flatten)	(None, 40000)	0
14	Dense (dense)	(None, 5097)	203885097
15	Activation_4 (ReLu)	(None, 5097)	0
16	Dropout_2 (dropout)	(None, 5097)	0
17	Dense_1 (dense)	(None, 23)	117254
18	Activation_5 (SoftMax)	(None, 23)	0

Figure 12: Data visualization on cloud platform.

Table 8: Distribution of datasets into training, testing, and validation classes.

Crop classification	Data sets		
	Training	Testing	Validation
Percentage	80%	10%	10%
Accountable data	2586	314	344
Total		3244	

4. Results

4.1. Temperature Data on Cloud. As the system is implemented using Internet of Things to analyze the data of temperature achieved inside the solar collector and drying chamber, Figure 12 illustrates the temperature variations captured by the system throughout a day.

4.2. Deep Learning Approach. For evaluation of our proposed deep learning approach, we carried out several experiments; performance of proposed approach is evaluated with the existing methods for crop image classification. Crop images of size are accumulated in JPEG, with image of

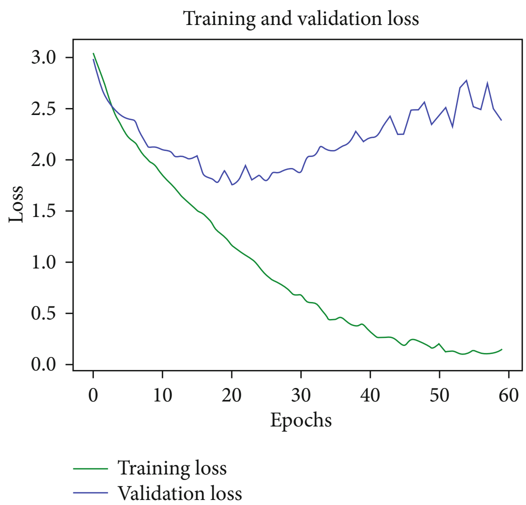

Figure 13: Accuracy training and validation loss.

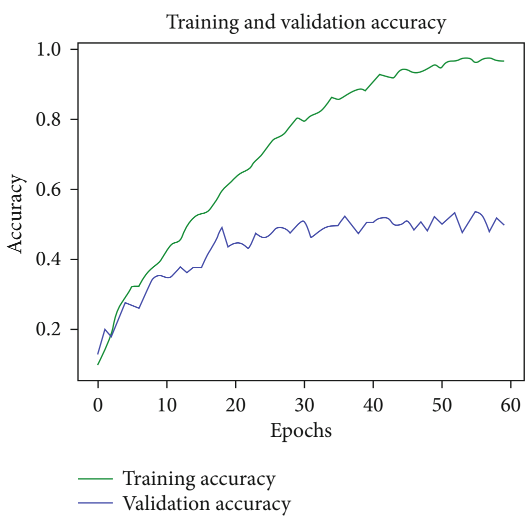

Figure 14: The accuracy curve for validation and accuracy.

high-definition (HD) resolution. Dataset contains data in red-green-blue color and contains 8 bits/pixel.

The data taken into study is taken from the Internet, having 3244 number of images of 23 different crops. After data preprocessing, the dataset was splitted into training test set. For training set, 80 percent of data is used as compared to the test dataset of 10 percent. Furthermore, during model fitting, 10 percent of data involved in training is used for validation; in Table 8, data distribution is given for training, testing, and validation of a model.

For this experimental implementation, we use stochastic-gradient-decent for optimization along with adaptive-learning rate β. As the epoch increases the value of adaptive-learning rate also changes, value varies in accordance with epoch number.

4.3. Result Analysis of Crop Image Classification Using CNN. We achieved 97.30% accuracy by using our proposed approach. The accuracy behavior of training vs. validation loss and the implementation of the proposed approach on the dataset are presented in Figures 13, with an evidently substantial improvement and proposed approach accuracy, which can be observed in Figure 14.

5. Conclusions

Internet of Things is playing crucial role, and blending of Internet of Things with other technologies such as machine learning, deep learning, and artificial intelligence can increase the impact of this beautiful technology. In this paper, we blended the Internet of Things with deep learning to enhance the productivity of the solar dryer and trained system with 3244 images as an input and achieved an accuracy of 97.30% to identify the exact crop and to set the desired temperature range required for the specific crop to dry.

Data Availability

The data is incorporated in the manuscript and will be available on request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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