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A Study on Mushroom Pest and Diseases Analysis System Implementation based on Convolutional Neural Networks for Smart Farm

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Abstract

Recently, along with the 4th industrial revolution, research on IT convergence technology that is aiming for eco-friendly agriculture is under way, and smart agricultural technologies utilizing artificial intelligence techniques are being studied in various forms. In general, the status and size of the crops produced from the farms are analyzed by image processing, and they are used to classify the quality. This paper proposes a system for analyzing the pest status of mushrooms cultivated in mushroom plantations using CNN, a machine learning algorithm that is becoming popular in the image recognition field. The mushroom images are analyzed by the CNN analysis module to determine similarity with other images learned according to the similarity measurement technique based on the Euclidean technique.

Keywords*: Mushroom, Disease and Insect Pest, Feature Extraction, Image Analysis*

1. Introduction

As ICT technology and the traditional industries of production, processing, distribution, and service are converged and integrated, the fourth industrial revolution has begun. In particular, the vast amount of data gathered through the Internet of Things has been sophisticatedly analyzed by artificial intelligence and this opens new research fields. Before the fourth industrial era, the results of smart farm research, which combines IT and agriculture, have been published in various forms. The research for smart farm has focused on analyzing the present state of agricultural products[1-2]. Particularly in pest analysis research, various image filtering techniques and edge extraction techniques have been used for the image analysis of the product. However, the disease image analysis and results have a limitation that they should be analyzed based on the image data stored in the existing database. In addition, the previous pest information analysis system, based on the analysis of formal data, has only been capable of analyzing the image after pest occurrence rather than predicting and preventing pest data.

Nonetheless, various methods have been recently studied to solve the problems of the existing pest information retrieval system based on Big data, which is the core of the fourth industrial revolution. Artificial intelligence technology research for systems to learn, evaluate, and predict the pest information and pest image generated by online and offline are being conducted. Artificial neural network, which is one of the artificial intelligence learning methods, is a learning technique that is formed by modeling neurons, which are objects that act as information transferred in the human nervous system. It is a learning technique that provides high recognition results in various recognition fields

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(speech recognition, image recognition, natural language processing, *etc*.)[3-4]. The artificial neural network model has a structure in which output and learning are repeated in neurons.

However, existing artificial neural network models have a low accuracy rate and some performance problems. Recently, however, studies on deep learning that solve these problems have been announced, and various research on voice and images have been conducted. Deep learning algorithms include RBM, DBN, Recurrent Neural Network (RNN), Deep Neural Network (DNN), and Convolution Neural Network (CNN). CNN especially shows a high recognition rate in image analysis. CNN is a classification model that learns and identifies what an image is when it is input into a composite neural network[5-6]. When an image is given, the CNN model uses a method of reducing the image through the convolution layer, the pooling layer, and the feedforward layer, and it finally extracts and classifies the features from the image. This paper proposes a system for integrating mushroom pest information retrieval for smart farm implementation based on CNN[7-8]. The pests of crops can be visually confirmed by the symptoms of the crops, but most of them are hard to find unless found by experts. Because mushroom crops having a variety of shapes, it is difficult to recognize their images from other ordinary crops[9-10]. As external factors, such as light, cause the color of infected mushrooms to change and makes it difficult to analyze their images. To solve this problem, a technique is proposed to analyze the image of mushroom pests using CNN, an artificial intelligence learning machine with a high recognition rate for mushroom images, and to provide various types of mushroom information with a high similarity. The proposed system collects mushroom pest insects that appear in the field in real time and applies them as input images to the Convolution Layer, Pooling Layer, Activation Function and Fully Connected Layer.

2. Related Work

Study [8], a region-based, fully convolutional network for fast and accurate object detection, has been proposed based on the experiment results. This study evaluates the performance of fine-tuned ResNet for object classification of our weeds dataset. Analyzing the ResNet with our small weeds dataset found that this architecture is more prone to over-fitting despite its higher level of accuracy. Several methods can be used to prevent over-fitting, such as adding dropout layers and stochastic augmentation of the training dataset. For this reason, we used a residual network along with dropout techniques for reducing the over-fitting of the network. Moreover, a combination of region proposal networks with fully convolutional networks were used to get better detection accuracy in the purpose of farmland weeds detection. Furthermore, this study projected the comparison between different deep CNN models as well as different object detection models. The dataset of farmland weeds detection is insufficient to train such deep CNN models. To overcome this shortcoming, data augmentation was performed and the augmented data was used along with the proposed ResNet to achieve a significant outperforming result from our weeds dataset. We achieved better object detection performance with Region-based Fully Convolutional Networks(R-FCN) technique which is latched with our proposed ResNet-101.

Study [11] proposes a plant leaf classification using shape descriptions. First, the algorithm needs to segment the plant leaf from the remainder of the image via the GrabCut algorithm. Next, the researchers can get shape descriptions using Scale-Invariant Feature Transform(SIFT), or Histogram of Oriented Gradient(HOG). After the shape descriptions have been acquired, they will be coded using the Locality-constrained Linear Coding(LLC) algorithm. Then, this description is represented by max pooling. Each final representation is utilized to classify into the Support Vector Machin (SVM). Through

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several experiments, the researchers could compare each description extraction method to classify the plant leaf, and find a suitable method on various systems.

Study [12] proposes a method of distinguishing edible mushrooms from non-edible mushrooms using a Principal Component Analysis(PCA) algorithm. This system functions by projecting a mushroom image onto a feature space that spans the significant variations among known sets of mushroom images. Mushrooms possess certain significant features such as its stalk size, cap shape, *etc*., and PCA extracts these dominant features and these are the eigenvectors of the set of mushrooms. The projection operation characterizes individual mushroom images by a weighted sum of the eigenvector features to recognize a particular mushroom, so it is necessary only to compare these weights to those individual ones. The performance of the proposed method showed around 85%~96% success rate that increases with the number of training images; hence, proves to be a reliable algorithm for the recognition of mushrooms.

3. Proposed Mushroom Disease Insect and Pest Analysis System

3.1. System Overall Structure

Figure 1 shows an overall structure of the proposed system. Our system consists of Manager Interface for learning analytical model, User Interface for browsing results of request analysis, Convolutional Layer for extracting feature map after calculating with filter, Pooling Layer for reducing the image, Activation Function for converting feature points into non-linear points in neural networks, Fully Connected Layer for classify feature vectors, and Database for storing pest information data. When the manger input the mushroom pest image data to be learned by the administrator through the Web interface, it performs learning on the new learning target image in manager interface. This consists of Convolutional Layer, Pooling Layer, Activation Function, and Fully Connected Layer for building the CNN Model in our mushroom pest image analysis system.

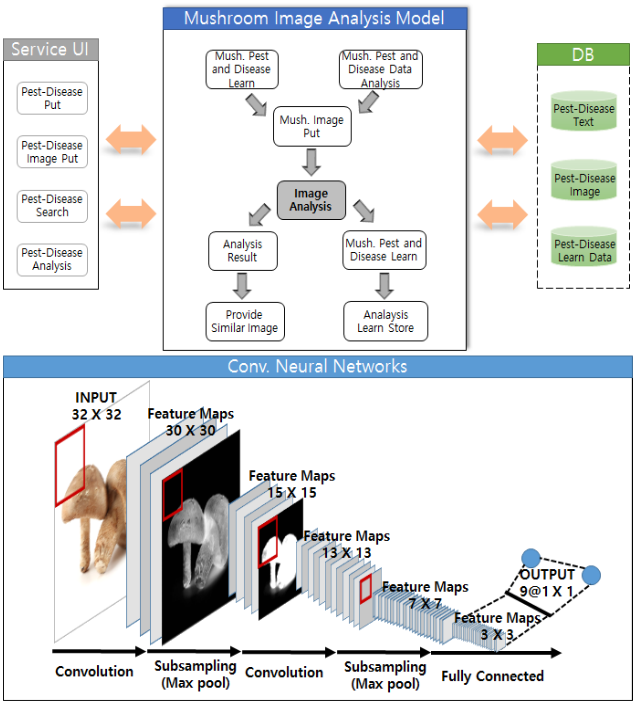

Figure 1. Mushroom Disease and Pest Image Analysis System Process Concept

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3.2. Pseudocode for System Design

Figure 2 shows the pseudo code of the proposed mushroom pest image analysis system. When a mushroom pest image is inserted, it is divided into learning module and analysis module, respectively. When the mushroom pest image data is inserted, it extracts the RGB pixel values from the image data and converts it into grayscale in order to increase the processing speed of the feature vector through the learning module requested by the administrator. Convolution of the Filter Kernel is performed by passing the adjusted pixel value to the *Conv ()* method. The result of the convolutional operation is composed of a feature map by adjusting the value of pixel according to the weight of the filter and then by calculating the sum. After passing the Feature Map to the *Activation Function ()* method, the optimal value of the filter is adjusted through the artificial neural network. Then, the image can shrink as well as get the maximum value in the pixel area by the *MaxPool ()* method. In the *Fullycon ()* method, when the reduction range of the image pixel reaches minimum size, it aligns as an array one dimension and stores it into the learning module. In the analysis module, the process is the same as the learning module when the user performs an analysis for the mushroom disease image acquired in the cultivated area. That is, the Grayscale translation, the Convolutional operation, the Kernel Filter adjustment of the Activation Function, Image reduction by MaxPool and a fully connected layer are processed. Then, the Euclidean distance measurement method is used to measure the similarity between the value of the extracted model and resulted one. The final results are browsed according to high similarity through the user interface.

```
BEGIN
FUNCTION main()
    sequence ImageRead(),  sequence ImageGrayscale()

IF learn THEN
    FUNCTION convolutional()
    FOR cnt = 0 to width DO
      FOR cnt = 0 to height DO
         FOR cnt = 0 to mask_w DO
             Image = Image * mask
         END
         sequence Acivation()
         Image = MaxPool(Image)
      END
    END
    sequence Fullycon()
    sequence Feature_arr_store()
ELSE IF test THEN
   FUNCTION convolutional()
    FOR cnt = 0 to width DO
      FOR cnt = 0 to height DO
         FOR cnt = 0 to mask_w DO
             Image = Image * mask
         END
         Image = MaxPool(Image)
      END
    END
    sequence Fullycon()
    sequence feature_arr_load()
    sequence Uclidean distance()
ELSE
END
```

Figure 2. Mushroom Convolutional Logic Pseudocode

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3.2.1. Convolutional Layer

A convolutional layer is a single layer neural network consisting of a function to convert into filter values to extract features from mushroom images. Figure 3 shows the convolutional calculation of mushroom images. The kernel filter detects how much the weights of feature data of mushroom images are reflected. When it is applied to the neural network, it becomes an important element to assess whether features can be extracted from the data.

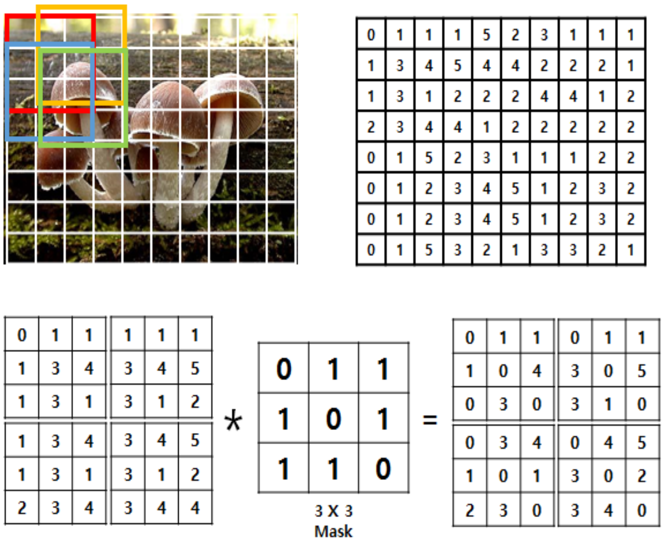

Figure 3. Convolutional Process Structure

Figure 3 shows the flow chart of the convolutional process. When the data of mushroom disease and pest images in the size of 10*8 pixels is entered, the size of the kernel filter becomes 3*3 as seen in formula (1). The convolutional layer processes the kernel filter in a convolutional product to extract feature points from the mushroom disease and pest images.

$$e[i][j] = (F * G)[i][j] = \sum_m \sum_n F(m,n)G(i-m, j-n) \tag{1}$$

$$W_2 = \frac{(W_1 - F)}{S + 1} \tag{2}$$

$$H_2 = \frac{(H_1 - F)}{S + 1} \tag{3}$$

In formula (1), G is the pixel value of an input image. When the convolutional product calculation of Matrix F in the filter kernel is processed, C is obtained. In the overall image, S represents the moving range of the filter. When S is moved to the right by 1, the size of the image pixel is adjusted according to formulas (2) and (3). In formula (2), W1 is the width of the input image, and W2 is the size of pixel that is reduced after calculation. The calculation of formula (3) is similar to that of formula (2), representing the size of the pixel that is processed after a convolutional product calculation according to the height of the image. In Figure 3, the example of data processing and calculation shows the reduction of pixel size to 3*3 according to 3.5 = (10 – 3)/1 + 1.

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3.2.2. Activation Function

The activation function uses the learning method of producing a neuron and recalculating the value that has been calculated with the neuron in back propagation. In this case, the ReLu function of formula (4) is used as an activation function. It is more efficient than Sigmoid including an exponential function and process of negative numbers under 0 as 0 unconditionally. It is performed after a convolutional calculation to increase the accuracy rate of mushroom disease and pest images that have a low recognition rate.

$$f(x) = \max(0, x), \qquad f(x) = \begin{cases} x, & x > 0 \\ 0, & otherwise \end{cases} \tag{4}$$

3.2.3. Pooling Layer (Convolutional-Max Pooling)

In Figure 4, the stride of the 3*3 filter is applied as 1 in the mushroom disease and pest images. The mask (filter) is applied, being moved by a cell to the right and downwards to obtain a feature map, in which the maximum value within the 2*2 pixel range will be searched for and chosen as the value to represent the features of the range. In addition, the feature vector will be reduced via the max pool stage to reduce the image data size.

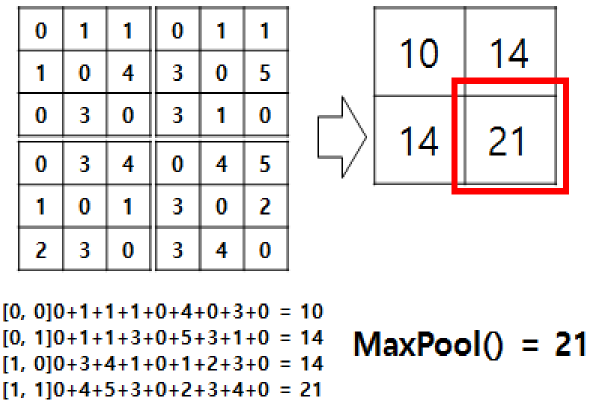

Figure 4. Pooling Process Structure

3.2.4. Fully Connected Layer

In Figure 5, the fully connected layer can be used as a feature map that has feature points extracted by putting the minimized sequence in one dimension. The one-dimensional feature map extracted with a learning module calculates Euclidean distance from the feature map of a different image and measures similarity according to distance. In formula (5), p is the learned value, and q is the value of the input image. The outcome of similarity is measured by repeating as much as the learned n.

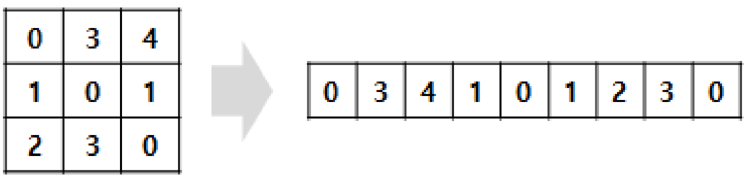

Figure 5. Fully Connected Process Structure

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$$\sqrt{(p_1 - p_1)^2 + (p_2 - p_2)^2 + \cdots + (p_n - p_n)^2} = \sqrt{\sum_{i=1}^{n} (p_i - q_i)^2} \tag{5}$$

4. Implementation Result and Evaluation

4.1. Administrator Interface

Figure 6 shows the interface of the manager to enter basic data that are specialized data to enter and study the mushroom disease and pest information. Of the entered data, images are saved by the outcome values of the learning data. It was implemented in the PHP-based Apache2 web container environment with the CNN module learned through the implementation of Java Class. MySQL was used for meta-data to provide information, and FileSystem was used for learning data.

Figure 6. Mushroom Disease and Pest Data Input UI, Input Data Result

4.2. User Interface

Learning occurred with approximately 1,500 mushroom images obtained from specialized data about mushroom diseases and pests including the Forest Mushroom Research Center [13] and the Agricultural Technology Center of Gumi [14] and from ImageNet [15], an image search service for research purposes. Outcomes were obtained after ten repeats of learning at the neural network of each layer with relatively lower weights being applied. Figure 7 shows the images of mushroom diseases and pests that had been collected and the image data of learning outcomes.

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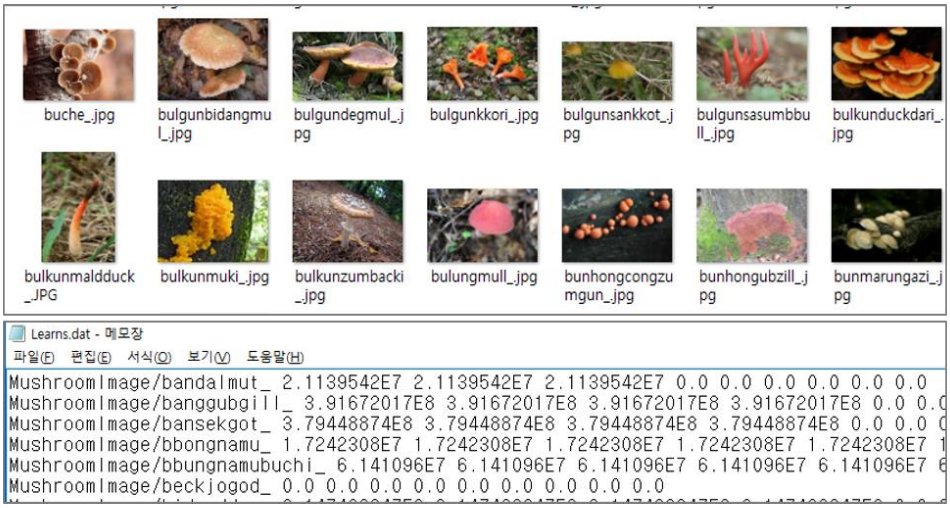

Figure 7. Image and Learned Data-Table

Figure 8 shows the random sample images of mushrooms(shiitake-mushroom) obtained from the web. They represent the analysis results of the top ten images analyzed with the analysis system for mushroom diseases and pests.

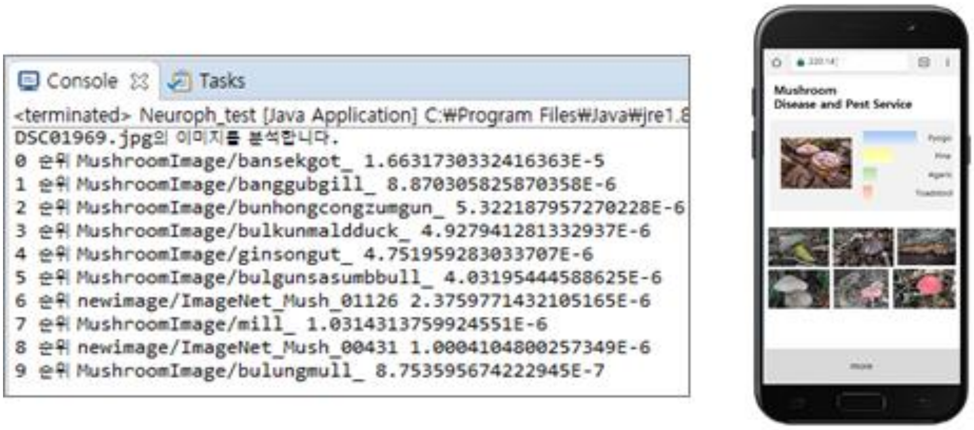

Figure 8. Test Image Result(Left), SmartPhone UI(Right)

4.3. Time Cost Evaluation

The proposed system was subjected to development and experiment in the following environments: the main-processor was intel i7-4790 3.6Ghz, and main-memory was DDR3 12 Gbyte ram, and GPU was NVidia Geforce GTX 1070, and secondary memory unit was SSD 256 Gbyte. In Figure 9, the learning time was measured with an activation function set as a single function in the CNN learning model. It used 1,100 learning image samples the size of 100~200 Kbyte and took 49 minutes to analyze them. In Figure 10, analysis performance time was measured by averaging 1.51 sec as to the learning model at the requested 50 times analysis at analysis image of about 100 Kbyte.

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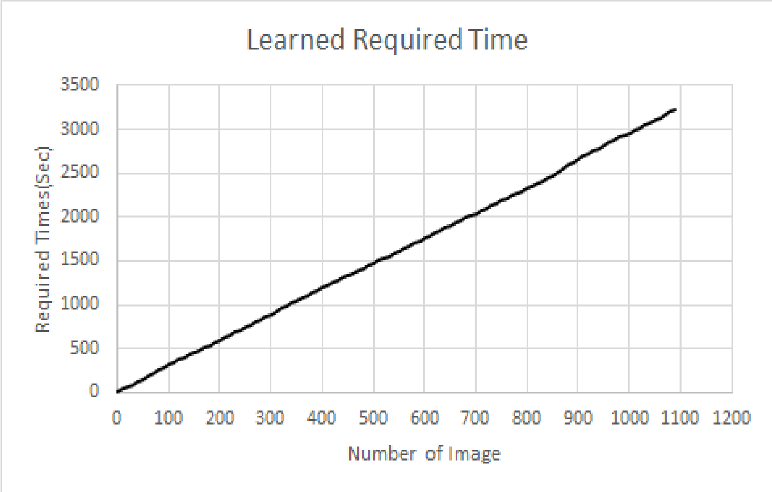

Figure 9. Learned Required Time Evaluation

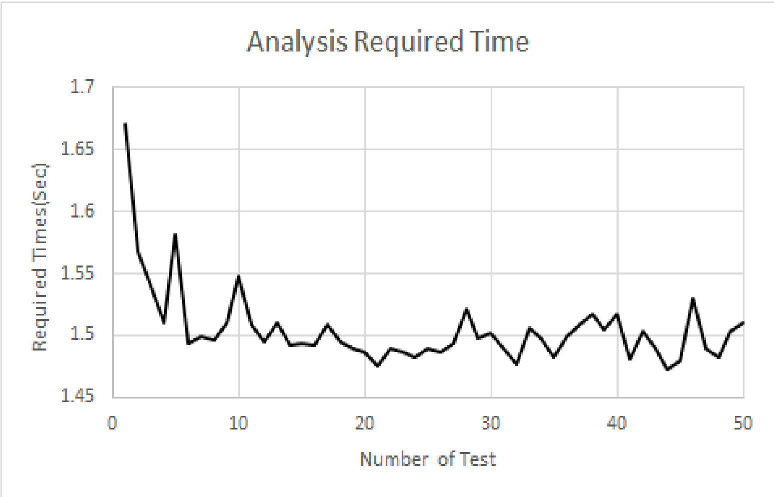

Figure 10. Analysis Required Time Evaluation

4.4. Relative Evaluation

The studies of [8, 11-12], similar to the one proposed in Table 1, selected six items for comparison and evaluation. These items were used for comparison and evaluation in terms of function fit for a search system for mushroom diseases and pests rather than performance. Previous studies that analyzed the images of mushroom diseases and pests used SIFT, HOG, and PCA and applied a traditional technique to the image processing to analyze feature points. They, however, had a couple of problems including a need to add another algorithm to image alteration(size and rotation). Meanwhile, ResNet has a problem of the exponential increase of learning time due to the infinite increase of layers. With OpenAPI, it is difficult to analyze intuitively or improve an algorithm. The proposed study implemented a Java-based CNN algorithm to extract an optimal value from the analysis results of image data. Its excellence was demonstrated in reducing the cost of the learning processing by applying a learning algorithm based on an artificial neural network and using an index of dimensional array. In addition, it was implemented to be optimized for the alternation(size, rotation) of mushroom disease and pest images.

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Table 1. Comparison Evaluation with Existing study

	[8] Study	[11] Study	[12] Study	Proposed Study
Mushroom Image Analysis Algorithm	ResNet	SIFT, HOG	PCA	CNN
Image Change(size, rotation)	X	X	X	O
Comparison of Image Pattern	ANN Learning	SVM	Eigenvector Features	ANN Learning
Learning Image Inclusion as often as Analysis Module	O	O	O	X (Dimension Array Index)
Open API Use	X	O	O	X
Integrated System	O	X	X	O

5. Conclusion

The present study proposed a CNN-based system to analyze mushroom disease and pest images and implemented a learning and analysis module for mushroom diseases and pests by constructing a manager interface, user interface, and CNN model with convolutional layers, pooling layers, activation functions, and fully connected layers. A qualitative assessment was carried out for the implementation results to compare them with previous research, and the results by time units were measured to assess learning performance. Providing measurements based on the low-performance hardware and a short period of learning, the learning model had no problem with recognizing similar mushroom objects but had a long way to go until making an accurate judgment about the symptomatic characteristics of mushroom species and diseases and pests. A follow-up study will assess the performance of the proposed system after upgrading the hardware performance, optimizing the analysis system, and increasing the learning amount of the learning model.

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