MUHAMMAD AL-XORAZMIY
NOMIDAGI TATU FARG'ONA FILIALI

FERGANA BRANCH OF TUIT
NAMED AFTER MUHAMMAD AL-KHORAZMI

"AL-FARG'ONIY AVLODLARI"

ELEKTRON ILMIY JURNALI | ELECTRONIC SCIENTIFIC JOURNAL

TA'LIMDAGI ILMIY, OMMABOP VA ILMIY TADQIQOT ISHLARI

4-SON 1(4)
2023-YIL

TATU, FARG'ONA
O'ZBEKISTON

ISSN 2181-4252

O'ZBEKISTON RESPUBLIKASI RAQAMLI TEXNOLOGIYALAR VAZIRLIGI

MUHAMMAD AL-XORAZMIY NOMIDAGI TOSHKENT AXBOROT TEXNOLOGIYALARI UNIVERSITETI FARG'ONA FILIALI

Muassis: Muhammad al-Xorazmiy nomidagi Toshkent axborot texnologiyalari universiteti Farg'ona filiali.
Chop etish tili: O'zbek, ingliz, rus.
Jurnal texnika fanlariga ixtisoslashgan bo'lib, barcha shu sohadagi matematika, fizika, axborot texnologiyalari yo'nalishida maqolalar chop etib boradi.

Учредитель: Ферганский филиал Ташкентского университета информационных технологий имени Мухаммада ал-Хоразми.
Язык издания: узбекский, английский, русский.
Журнал специализируется на технических науках и публикует статьи в области математики, физики и информационных технологий.

Founder: Fergana branch of the Tashkent University of Information Technologies named after Muhammad al-Khorazmi.
Language of publication: Uzbek, English, Russian.
The magazine specializes in technical sciences and publishes articles in the field of mathematics, physics, and information technology.

2023 yil, Tom 1, №4
Vol.1, Iss.4, 2023 y

ELEKTRON ILMIY JURNALI

ELECTRONIC SCIENTIFIC JOURNAL

«Al-Farg'oniy avlodlari» («The descendants of al-Fargani», «Potomki al-Fergani») O'zbekiston Respublikasi Prezidenti administratsiyasi huzuridagi Axborot va ommaviy kommunikatsiyalar agentligida 2022-yil 21 dekabrda 054493-son bilan ro'yxatdan o'tgan.

Jurnal OAK Rayosatining 2023-yil 30 sentabrdagi 343-sonli qarori bilan Texnika fanlari yo'nalishida milliy nashrlar ro'yxatiga kiritilgan.

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FARG'ONA - 2023 YIL

TAHRIR HAY'ATI

Eslatma! Jurnal materiallari to'plamiga kiritilgan ilmiy maqolalardagi raqamlar, ma'lumotlar haqqoniyligiga va keltirilgan iqtiboslar to'g'riligiga mualliflar shaxsan javobgardirlar.

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A Convolutional Neural Network For Classification Cotton Boll Opening Degree

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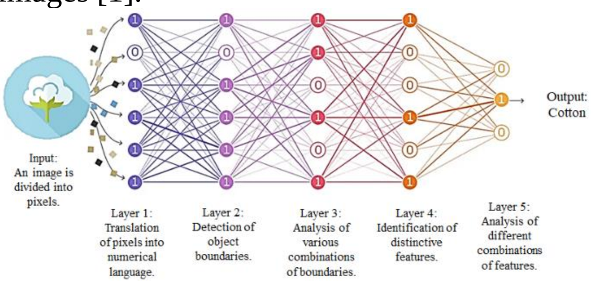
Abstract. The paper is devoted to the development of a cotton boll opening degree classification algorithm based on a convolutional neural network. A neural network consisting of convolutional layers, subsampling layers, and full-link layers was used in the study. The aim of the work is to classify cotton boll samples according to their opening degree. The classification criteria are minimizing the number of errors and achieving high accuracy. In the process of creating the algorithm, the data obtained by computing and image processing software were used. In this paper, a number of experiments were conducted with different parameters of convolutional neural networks and training samples to optimize the classification process. The final algorithm was tested on real cotton samples and demonstrated high classification accuracy.

Keywords. computer vision, convolutional neural network, image classification, image segmentation, recurrent neural networks, model training, epoch, layers.

Introduction. To date, one of the most popular mathematical models used in computer vision is the neural network model (Fig. 1), which is based on the work of neurons in the brain, and can be successfully used for object classification and recognition in video images [1].



Model of neural networks.

In order to recognize objects in the video image, the following steps can be performed. At the first step of detection, the identification of objects in the video image is performed. Object identification is performed using algorithms that analyze the pixels of the image, resulting in the extraction of object contours. The next step is to extract features that will be further used to distinguish one object from another. The differentiation can be done using machine learning algorithms that analyze the shape, color, texture, and other properties of the objects. The next step is to use machine learning algorithms to recognize objects in the video image. This step involves comparing the features extracted from the objects with a database of known objects and determining which object the extracted feature belongs to [2].

After training object recognition, we can classify cotton boll disclosure degree according to their images. For more accurate object recognition, it is necessary to build the algorithms according to the specific application and perform tuning of the following algorithm parameters: object detection threshold; object size, and shape.

Image classification is one of the machine learning techniques in which a computer recognizes and classifies images for the presence of certain objects or scenes. It is a process in which a computer model is trained in advance to classify images into specific categories based on a set of criteria that have been defined in advance. Typically, neural networks such as Convolutional Neural Networks (CNN) are often used for image classification, which is able to extract image features and use them for accurate classification [3]. Nowadays, image classification applications are widely used in various fields such as medicine, biology, geographic survey processing, vehicle license plate number detection, automatic face recognition, etc. Applying these methods for the classification of cotton boll opening degrees gives high-accuracy results.

Solution method. To achieve the objective, it is necessary to collect a dataset of cotton bolls’ image with 3 different disclosure rate containing, as shown in Fig. 2, captured with a video camera in a cotton field, under different weather conditions and time periods [4-10].

a. b. c.

Dataset of cotton bolls’ image with 3 different disclosure rate: a) - high cotton boll disclosure rate, b) - medium cotton boll disclosure rate, and c) - low cotton boll disclosure rate.

The dataset contains images of cotton bolls in several states and at different stages of cotton opening. Classification of images in the dataset can be done using machine learning and neural networks [11-13].

Let us list the most popular methods of image classification with the possibility of their application to the classification of cotton boll opening degrees:

- *1. Binary classification* - it can be used to divide cotton images into two categories (e.g. high cotton boll disclosure and low cotton boll disclosure).
- *2. Multi-class classification* - it can be used to divide the images into multiple categories (e.g. high cotton boll disclosure, medium cotton disclosure, and low cotton boll disclosure).
- *3. Image segmentation* - it can be used to divide an image into several areas according to their features (e.g. cotton without leaves, cotton with leaves, cotton with flowers, etc.).

To perform image classification in a software environment can be used various machine learning and neural network methods such as convolutional neural network (CNN) or recurrent neural network (RNN). These methods have high accuracy in image classification and are widely used in various fields including agriculture. CNN [14] was chosen as the machine-learning algorithm for cotton boll opening degree.

A Convolutional Neural Network is a type of neural network that is the main tool for image classification and video processing tasks. The basic idea of CNN is to use convolutional layers that perform an image convolution operation with filters to extract important features of an image [15].

These features are then processed in full convolutional layers that provide efficient image classification based on the extracted features. The filters in convolutional layers are defined by neurons that store the weights of the extracted features.

The main advantages of CNNs are:

- high-quality image classification;
- high learning speed due to the use of convolution;
- are robust to changes in scale and rotation of image positions;
- can automatically extract meaningful features from images, which facilitates the learning process [16].

Thus it can be considered that CNNs are the basis for many applications such as automatic face recognition, automatic vehicle license plate number recognition, medical image processing, and cotton boll opening degree recognition.

Methods for solving problem. Classification by cotton boll opening degree can be performed using a convolutional neural network. However, to create such a model, it is necessary to have data that contain information about the degree of cotton opening in the images [17].

The idea is to be able to use convolutional layers to learn features related to the degree of cotton disclosure in an image. Then, once the features are extracted, they are processed in full convolutional layers to classify the image into three categories: low cotton boll disclosure, medium cotton boll disclosure, and high cotton boll disclosure [18].

To create such a model, it is necessary to have a large enough dataset to train and test the model. The training set should contain images with different levels of cotton boll opening, as well as labels that indicate the appropriate category.

The model is then trained, in which it uses images from the training set to learn the attributes associated with cotton boll opening level. Once the model is trained, a test dataset can be used to verify its accuracy.

Thus, convolutional neural networks can be used to classify images based on the degree of cotton boll opening. As mentioned above, to create such a model it is necessary to have a large data set for training and testing the model, as well as for training the model on a sufficiently large number of epochs. This makes it possible to extract all the necessary features of images [19-22].

Below is a fragment of the trained model without data in Keras.h5 format. In this case, the code fragments were used to classify cotton bolls by their opening degree.

```
from keras.models import load_model
# TensorFlow is required for Keras to work.
import cv2
# Install opencv-python
import numpy as np
# Disable exponential representation for clarity
np.set_printoptions(suppress=True)
# Download the model
model = load_model("keras_Model.h5", compile=False)
# Download labels
class_names = open("labels.txt", "r").readlines()
# CAMERA can be 0 or 1 depending on your computer's default camera
camera = cv2.VideoCapture(0)
while True:
# Display the image from the camcorder
    ret, image = camera.read()
# Resize the raw image to (224 height, 224 width) pixels
    image = cv2.resize(image, (224, 224), interpolation=cv2.INTER_AREA)
# Show image in a window
    cv2.imshow("Webcam Image", image)
# Carry out image corrections with the numpy array and change its shape to the input shape of the model
    image = np.asarray(image, dtype=np.float32).reshape(1, 224, 224, 3)
# Normalization of image array
    image = (image / 127.5) - 1
# Predicts the model
    prediction = model.predict(image)
    index = np.argmax(prediction)
    class_name = class_names[index]
    confidence_score = prediction[0][index]
# Forecast display and confidence indicator
    print("Class:", class_name[2:], end="")
    print("Confidence Score:", str(np.round(confidence_score * 100))[:-2], "%")
# Monitor keyboard presses
    keyboard_input = cv2.waitKey(1)
# Esc keys on the keyboard for interruption
    if keyboard_input == 27:
      break
camera.release()
cv2.destroyAllWindows()
```

Thus, in this example, a CNN using Keras library and TensorFlow is applied to perform cotton boll classification according to its opening degree.

Results and discussions. To obtain information about the per-class accuracy, confusion matrix, per-epoch accuracy, and per-epoch loss during model training, various functions and methods from the TensorFlow library can be used.

For example, to get the accuracy per class, can be used the classification_report method from the sklearn.metrics module The report result is shown in Table 1.

Example of use:

```
python
from sklearn.metrics import classification_report
# Obtain model predictions on the test sample
y_pred = model.predict(test_data)
```

```
# Round values to integers
y_pred = np.argmax(y_pred, axis=1)
# Receive a report on classification accuracy
target_names = ['class1', 'class2', ..., 'classN']
print(classification_report(test_labels, y_pred, target_names=target_names))
```

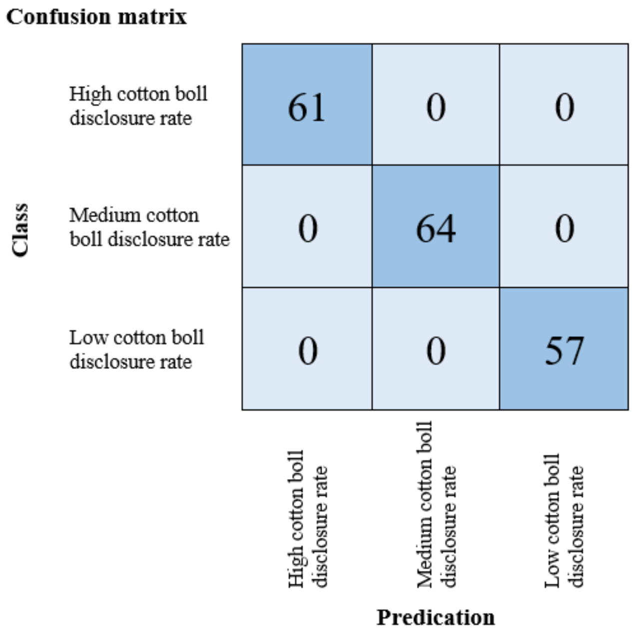
Table 1. Classification accuracy report

Accuracy per class		
CLASS	**ACCURACY**	**SAMPLES**
High cotton boll disclosure rate	1.00	61
Medium cotton boll disclosure rate	1.00	64
Low cotton boll disclosure rate	1.00	57

confusion_matrix method can be used from the sklearn.metrics module to obtain the confusion matrix (Figure 3).

Example of use:

```
python
from sklearn.metrics import confusion_matrix
# Obtain the confusion matrix
matrix = confusion_matrix(test_labels, y_pred)
print(matrix)
```

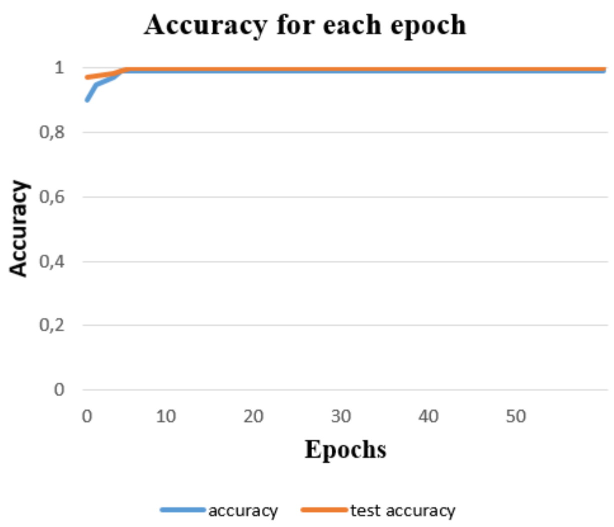


Confusion matrix.

To obtain sufficient accuracy (Fig. 4) and loss (Fig. 5) at each epoch, can be used the "callbacks" parameter in the "fit" method when training the model. For example, "History" class can be used from the TensorFlow library to store metrics for each epoch.

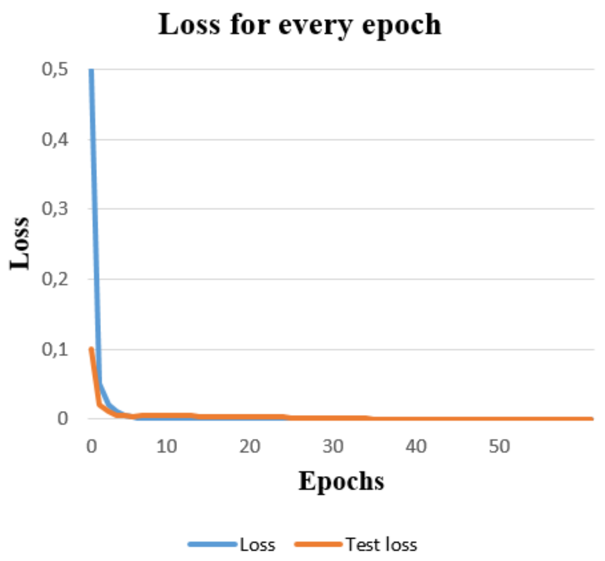
Example usage:

```
python
from tensorflow.keras.callbacks import History
# Create an instance of the «History» class to save metrics
history = History()
# Train the model by passing a "History" object to the "callbacks" parameter
model.fit(train_data, train_labels, epochs=10, validation_data=(test_data, test_labels), callbacks=[history])
# Get the values of the metrics for each epoch
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
print('Accuracy for every epoch:', acc, val_acc)
```



Graph of accuracy at epochs.

loss = history.history['loss']
val_loss = history.history['val_loss']
print('Losses for each epoch:', loss, val_loss)



Graph of loss on epochs.

Here, we used the validation_data parameter to pass the test sample and validate the accuracy and loss at each epoch. The metrics at each epoch are stored in the 'history' object and can be retrieved using the keys 'accuracy', 'val_accuracy', 'loss' and 'val_loss' [21,23-26].

Conclusion. This paper presented a convolutional neural network usage for classification cotton bolls according to their opening degree. The network was trained on a dataset consisting of cotton ball images divided into three categories of opening degree. The classification accuracy report showed that the network presented is reasonably high accuracy in classifying cotton. The plots of accuracy and loss at each epoch show that the network achieves the best accuracy at the last experiments and that the loss values start decreasing with each epoch. A confusion matrix was also presented, which shows classes those were correctly and incorrectly recognized by the network. As the confusion matrix shows, the most difficult image to classify is the medium-disclosure cotton boll image, which can be confused with the low-disclosure cotton boll image. Thus, the convolutional neural network presented in this paper has shown good results in classifying cotton bolls based on the degree of opening. This technology can be used to control and regulate the technological parameters of cotton-picking machines to increase the yield and speed up the process of harvesting.

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