The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 213 - 222

Classification of Defective and Non-Defective Products Using Convolutional Neural Networks in Quality Control

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Abstract
The arrival of convolutional neural networks (CNNs) has enhanced the progress of computer visualisation from many fields. However, most of the CNNs are rely on GPUs (graphics processing units) that could needthe large computations and it requires more cost to developthe setup. Therefore, most of the manufacturers haven't used the CNNs to inspect the defective items in theirfield. The researcher has developed a compact CNN-based model that not only achieves high performance on tiny defect inspection but can be run on low- frequency CPUs (central processing units) in this paper. This experiments indicate CNNs canbe compact and hardware-friendly for future applications in the automated surface inspect (ASI)in the selected manufacturing field.
Key words. Surface defective inspection; convolutional neural network; machine vision.

Introduction

The rapid and robust automatic quality inspection model has received increased attention in the quality control for identifying defective and non-defective products efficiently. In order to effectively find out the defective products in the manufacturing process, many methods have been used. But these methods have been effective only under specific conditions and complex which requires many more inputs for the process. So the main purpose of this paper is tobuild a deep learning model which will find the defective and non-defective products much efficiently with less complex.

The quality inspection is the most important part in the Manufacturing companies because it ensures the quality of the products by segregating defective products from the non-defective products. In the manufacturing process, the defective products is of low quality which affectsthe manufacturing efficiency and also reduces the recognition for that company in the market and the poor quality products is of no use which leads to the wastage of raw materials and resources.

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Only non-defective and high quality products will make profit to the company and gives company a potential strength to sustain in the market. However, in the quality inspection process many companies using artificial intelligence to detect the defects in the products butit relay more on human power and consumes more resources. Since the human capability is limited, the long term work leads to the inefficiency in the production which leads to the inefficiency in the quality check process. Hence it becomes mandatory to bring the automatic defect detection model in the quality check process.

With the huge development of technology in the field of Data Science, Machine Leaning and Artificial Intelligence and its applications, Defect detection models has been successfully implemented in the quality checking process of various industry Manufacturing products such asfabrics, steel slabs, glass productsand so on. These methods said to have differentdesigns with different algorithms to extract images and its features based on certain defect detection conditions.

Thistraineddeep convolutional neural networks (CNN) can extract powerful features automatically from the images and use those extracted features as the inputfor the purpose of defect detection and it also robust to noise with more efficiency. The researcher evaluate this CNN model experimentally on a dataset and achieve a fast detection result with a high accuracy.

Image classification model is a complex process that will be affected by various factors. Hence classification results are the basis for many environmental and socioeconomic applications.This classification of defective and non-defective products using convolution neural networks is an image classification model which will be able to differentiate between defective and non-defective products very effectively.

This model converts the non- readable product images into machine readable data and uses these data to predict whether the product is defective or non-defective. Thus by doing this the model is helpful in segregating defective products automatically and preventing mixing of defective and non-defective products together in the packing process thus by providing good quality check to the company.

Problem Statement

Quality checking and inspection processes in production and manufacturing companies are done manually by operators and people who during the work process due to personal problems, fatigue or illness, cannot work continuously without error. Due to the limitation in the human capabilities the segregation of defective products from the non-defective products may not done efficiently which leads to the delivery of defective or less quality products tothe customers, which reduces the brand name in the market as well as the recognition. Hence classification of defective and non-defective products using convolutional neural networks model in quality control automatic quality inspection system is proposed, based on artificial intelligence algorithms.

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Objectives Of The Study

- The main objective of this research study is to develop a deep convolution neural network which will automatically detect the defective and non-defective products and helps to segregate the defective products easily thus enhance the efficiency of quality check department.
- Since the quality check has been done manually so far in this selected company the time taken to segregate the defective and non-defective products is high, thus affects the productivity of the company. Hence the other objective of the study is to implement the trained convolution neural network to reduce the time taken in the quality check process thus by increasing the productivity.
- The secondary objective of this research study is to improve quality of the products, Brand Recognition of the products in the market and to improve customer satisfaction by providing good image classification model to segregate the products effectively, thus preventing delivery of less quality products to the customer.

Research Methodology

TOOLS USED

- Google Colaboratory
- Python 3.0
- Google Drive
- Web camera

In this study both the Primary data as well as the secondary has been used to train the model. The design of the model is based on convolutional neural network which is an image classification technique consist of 3 layers such as convolution layers, Pooling layers, Full connected layers each and every layers extract useful information from the images which later helps to find whether the product is defective or non-defective. The images features has been converted into machine readable format using a library called OpenCV in python. The input images has been given through web cam of the system and thus the captured image sent in to google colaboratory notebook where the program code is running. Google colaboratory is an online platform offered languages and library for the by google which provides free access to various machine data interpretation, analysis and prediction purposes. The machine language used here is python 3.0 which is very much efficient machine language for data interpretation and analysis. Python 3.0 is an open source machine language which consist of various libraries used for the Data interpretation purpose.

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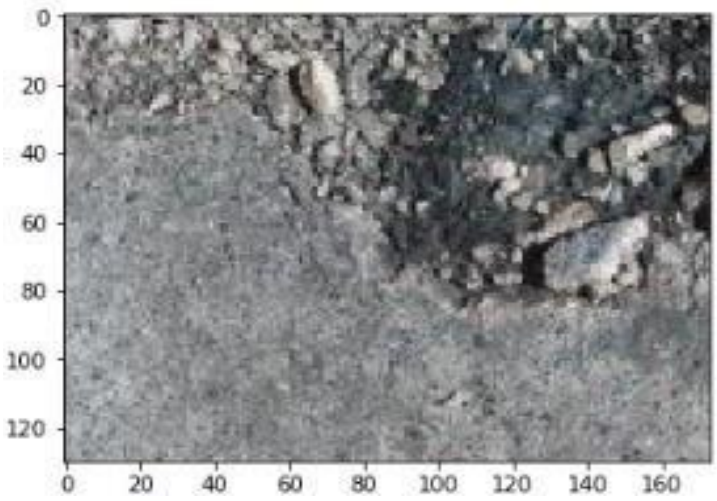
Data Analysis And Interpretation

NON-DEFECTIVE PRODUCT

DEFECTIVE PRODUCT

HOW THE MODEL PREDICTING THE IMAGES



Convolution neural network looks for various patterns in the given image. The image is divided into smaller matrix and this CNN model looks for various patterns and useful information in each of the smaller matrix of the given images. The layers can identifies the lines, corners and edges. These patterns are passed down into the deeper neural network layers to recognize more complex features. This property of CNNs is very good at identifying objects and patterns in images.

Three layers such as Conv, ReLU and Max Pooling (2X2) are applied to the images given especially in the crack of the image above. It can be seen below that the CNN architecture is concentrating on the crack area and the spread it throughout the surface.

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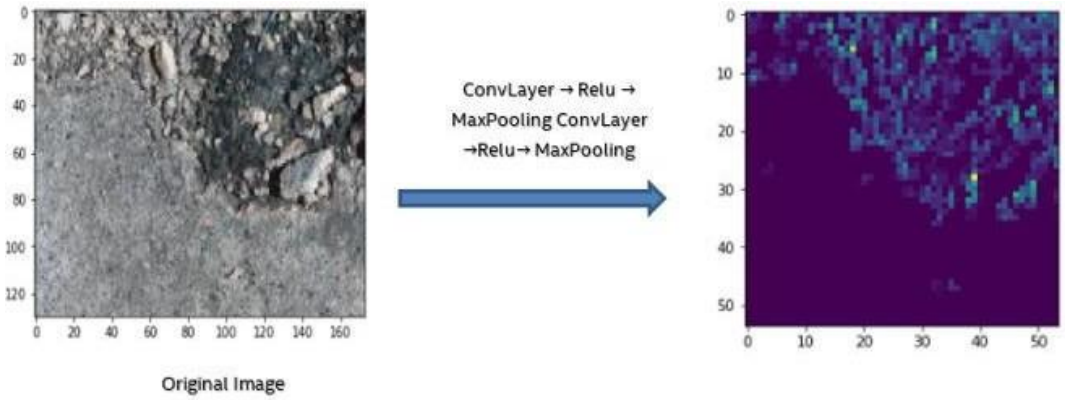

CREATING DATASET

- The first step in building an image classification neural network model is to create a dataset of images for the purpose of training the model.
- For creating the dataset, the pictures of the products should be taken. The researcher has taken pictures of 748 good quality products and labelled them as a non-defective products and also taken pictures of 878 damaged products and labelled them as a defective products in order to train the model.
- For better accuracy the number of pictures taken in each category may be increased. Now totally there are 1626 images of defective and non-defective products have been collected and ready for the purpose of training the model.
- These taken photographs have been saved in the google drive in order to import these pictures into the google colaboratory notebook.

MODEL BUILDING:

- The researcher using Google Colaboratory platform for the model building purpose and the computer language used here is Python 3.0.
- Google Colaboratory is a free online cloud-based Jupyter notebook environment that allows us to train our machine learning and deep learning models on CPUs, GPUs, and TPUs.
- Python 3.0 is a high-level, interpreted, interactive and object-oriented scripting language. Python is designed to be highly readable. It uses English keywords frequently where as other languages use punctuation, and it has fewer syntactical constructions than other languages.
- The first step is to upload all the images we have taken into the google drive
- The next step is to connect the google drive with the google colabjupyter notebook in order to load the dataset that we have created earlier.
- We are converting this non-readable data into a readable format with the help of libraries like os.listdir and cv2.imread.
- This os.listdir library reads all the images which is stored in the location (loc). This cv2 library converts all the images from non-readable image format into machine readable pixel

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format.

- OpenCV is a cross-platform library using which we can develop real-time computer vision applications. It mainly focuses on image processing, video capture and analysis including features like face detection and object detection. This library converts non-readable images into machine readable pixel format.
- The dataset has been divided into two categories and labelled as 1 and 0, 1 for defective products and 0 for non-defective products.
- After labelling like that, the next step is to import keras library which we are going to use that for predicting defective and non-defective products.
- This model will predict based upon the probability between those two categories whichever is having high value will be shown as a prediction.
- For the purpose of using probability (i.e one hot coding) we are importing another function called to categorical which is also an inbuilt function in keras library.
- As mentioned above the convolutional neural networks has three layers i.e convolutional layer , pooling layer and fully connected layer and after that one more layer we have to use in order to make the predictions with the help of the activation functions i.esoftmax function.

- **Softmax Activation Function** :

➢ The softmax function, also known as softargmax or normalized exponential function, is a generalization of the logistic function to multiple dimensions. It is used in multinomial logistic regression and is often used as the last activation function of a neural network to normalize the output of a networkto a probability distribution over predicted output classes.

➢ softmax is an activation function .Softmax is exponential and enlarges differences - push one result closer to 1 while another closer to 0. It turns scores aka logits into probabilities. Cross entropy(cost function) is often computed for output of softmax and true labels (encoded in one hotencoding).

- In order to import all the required layers and activation functions of the convolutional neural networks we have to import below mentioned functions from the keras library

❖ Sequential
❖ Conv2D
❖ Maxpooling2D
❖ Dropout
❖ Flatten
❖ Dense
❖ Activation
❖ Batch Normalization

- Here in this model the researcher has used three convolution layer, three pooling layer, three Batch Normalisation layer with Rectified linear unit as an activation function and one flatten

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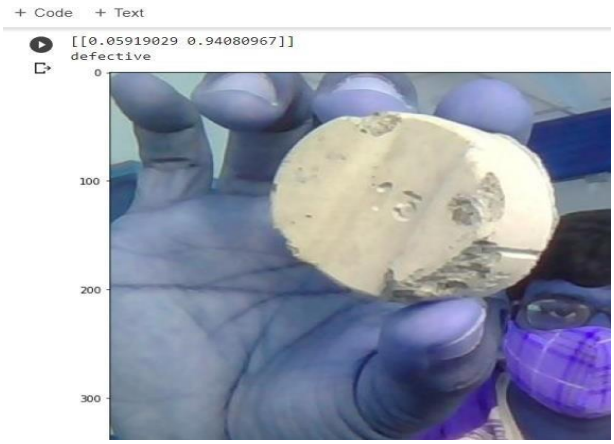
layer with softmax as an activation function which is used to predict whether the product is defective or non-defective.

- With the help of all these layers and functions this model will find a pattern among the images and learn as many parameters it can and use those parameters in the process of image classification.
- Once the initialization of layers has been completed we are going to split the dataset into two categories train data set and test data set. Train set is the one which is used to train the model whereas the test data set is used to test the predictions of the model.
- About 75 percentage of the dataset is used as a training set and 25 percentage of the dataset is used as a test set in this model.
- This splitting of dataset can be done easily by importing a function called train test split from sklearn library.
- Once the splitting of dataset done the next step is to train the model using the training dataset. This model achieved **98.20** percent of training accuracy.
- Once the training has been done, the next step is to test the model using the function evaluate with the test data set. Here the researcher has achieved **92** percent of test accuracy.
- In order to increase the accuracy we need to use more images and we need to train model with good accuracy by altering different parameters.

Predictions On Unknown Images:

- So far we have seen the trainings and predictions on already known dataset which means the data has been already revealed to the model but now we are going to take pictures from the internet directly or using the webcam and use those images to make the predictions and also to check whether the model is predicting correct or not.
- Webcam is a tool which is used to capture real time images of the products and save in the google colab gallery later use those saved images as a input for the purpose of predictions.

Prediction Using Web Camera:



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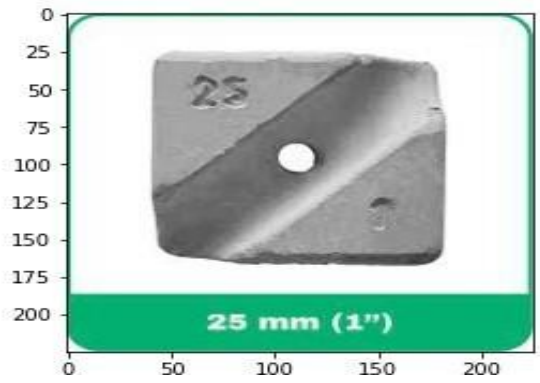
- In the above picture the researcher has taken the specimen and brought itnear to the webcamand took a picture using the capture button. This captured images are in the gallery of the google colabjupyter notebook as photo1.jpg.
- We are converting this non-readable data into a readable format with thehelp of libraries like os.listdir and cv2.imread.
- This os.listdir library reads all the images which is stored in the location (loc). Thiscv2 library converts all the images from non-readable image format into machine readable pixel format.
- After the conversion The researcher used this model to predict the imagewhether it is a defective product or non-defective product.
- This model is exactly predicting this damaged product as a defectiveproduct with a probability of 94.08 percentage as defective and 5percentage as non- defective.

Prediction Using Images From The Internet

```
k7 = cv2.imread('/test3.jpg')
kt7 = cv2.resize(k7,(70,70))
print(model1.predict(kt7.reshape(1,70,70,3)))
print(p[np.argmax(model1.predict(kt7.reshape(1,70,70,3)))])
plt.imshow(k7)
plt.show()
```

```
[[0.97978824 0.02021176]]
non_defective
```



- In the above picture the researcher has taken the specimen from the internet and saved it in the gallery of the google colab jupyter notebook as test3.jpg.
- We are converting this non-readable data into a readable format with the help of libraries like os.listdir and cv2.imread.
- This os.istdir library reads all the images which is stored in the location (loc This cv2library converts all the images from non-readable image formatinto machine readable pixel format.

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- After the conversion the researcher has used this model to predict the imagewhether it is a defective product or non-defective product.
- This model is exactly predicting this good quality product as a non-defective product with a probability of 97.97percentage as non-defective and 2 percentage as defective.

Conclusion

As Ramtech construction covers and blocks private limited is producing various products like Concrete Cover Blocks, Roof Tiles, Waterproof Coatings, and Vermiculite. The production capacity of this organization is high and it is producing35,000 units per day.Averagedefectiveproductsproducedperdayis1200- 1500productsandtheresourcesutilized to segregate these defective products from the non-defective products is huge and it involves utilization of manpower, time consumption will be high, human errors will be there.

Hence this automated defect detection model will find defective products from the whole productions without human intervention and thus by eliminate the wastage of human power, unnecessary time consumption and also reduces the human error. The proposed defect detection system was designed for multi-class detection, so the system could naturally be extended detect a range of different defect types in multiple materials.

The defect detection system described in this work could also be trained to detect defects in additive manufacturing applications. This defect detection system having 92 Percent of accuracy which means out of 100 products this system predict 92 products accurately. So to increase the accuracy of this model we need to have more data and the careful tuning of parameters is required. This model makes the work of quality control department easier and also ensures the delivery of non- defective quality products to their customers, thus by improving the customersatisfaction.

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