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Early Detection of Invisible Spoilage on Apple Fruit Using CNN and Texture Analysis

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Abstract: *In an Era of Ai world where Artificial Technology plays crucial role. The population and pollutions has been increasing, ensuring a growing supply of natural fruits is challenging because natural process take a long time to overcome from these chemical treatments were applied to enhance growth rate and also due to overtime preservation apples are experience spoilage which can people not detect easily then its effect people's health and increases people's health issues to avoid all this problem and provide the fresh apple fruit. This project focus detects invisible spoilage on the surface of apple fruit with the help of AI techniques. Convolutional Neural Network (CNN) were employed for Deep Learning is applied for detect extract features on Apple images Additionally, conventional machine learning techniques, including Local Binary Pattern (LBP) and Gray Level Co-Occurrence Matrix (GLCM) are utilized to capture pixel feature changes. The collected dataset is classified into training and testing to train the model and evaluate its result prove that system can reliably sort Apples into two parts Healthy and Spoiled, even when human eye can't detect spoilage.*

Keywords: Texture Analysis, Feature Extraction, CNN, LBP, GLCM

I. INTRODUCTION

Nowadays many people are facing personal health problems. In the modern junk-food world, many Gen Z individuals follow unhealthy diets. Because of these unhealthy food habits, nutrition and healthy foods have become very important. In this situation, it is realized that the foods given by nature are the best. Therefore, focusing on fruits, as they are very healthy for humans and beneficial for the whole body [1]. In this AI world advance technologies are appearing like Image processing in (CNN), Machine and Deep learning have varied applications in biological and in medical domain. It is observed that many peoples and farmers in India are unknown about the new technologies and minimal resources and hence they are not in a position to use the resources what they have in increasing the productivity [2]. Also, the agricultural and food industries have long benefited from advancements in computer vision techniques, which have transformed the automation of various tasks, including the inspection and classification of food products' attributes and features. Many Software's are developing for the detection of spoiled fruits or diseased fruits which are helps the farmers for identifying the disease [3]. Image processing plays an important role in the spoiled or diseased detection process field. It has lots of applications to measure the quality of fruits and vegetables. There are different types of diseases found during the cultivation of crops that affect the freshness of the different fruits, especially apples [4]. By detecting the disease with the image processing technology, the farmer can get to know the type of disease and can take precautionary measures. With this technology. Numerous approaches can be used to identify disease in its early stages, and this will help to maintain the apple fruit freshness for a long time [5]. It's very helpful in agricultural fields for farmers because human eyes can't detect invisible texture on apple. The traditional way to identify the freshness of an apple fruit is to look at it with your naked eye, but it is not effective. However, with the help of the digital method, apple fruit detection can be accurate and save time. The people who ever Apple lover its very beneficial. The farmer can instantly identify the disease of the fruits in bulk quantity. It is imperative that, Agriculture is one of the biggest sectors in Indian economy and this sector is undoubtedly the best employer of Indian

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industries [6]. In fact, the industry of agriculture plays a vital role in enhancing the economy of the country. The rise of artificial intelligence, especially deep learning algorithms, has opened new opportunities for addressing these challenges. Over the past decade, neural network architectures like Convolutional Neural Networks (CNNs) and GLCM and LBP have been consistently improved and applied to image classification tasks with impressive results. These models excel at extracting hierarchical features from images, making them ideal for detecting subtle patterns in fruit surfaces that indicate damages. For example, CNNs have been used in various agricultural tasks, from predicting crop yields to identifying diseases, showing their versatility and strength. However, despite these advances, the specific area of classifying apple surface damage in packing plants remains underexplored, with current systems often limited by small datasets, narrow model comparisons, or a lack of optimization for real- time industrial use. This proposed research talks about disease detection of the fruits by developing a CNN model. The productivity of the crops like Apple, Grapes and Mango can be enhanced by using this model as this model can be used to detect the disease of the fruits instantly. In this proposed research, Apple fruit database has been considered, to detect the disease as a means for research. The different types of diseases an apple can get affected like Blotch apple, Rotten apple and Scab apple. If the apple has not affected with any of the disease, it is regarded as Normal apple.

II. LITERATURE REVIEW

[7] Martín Molina and et.al, described Apple damages classification: Using the best convolutional neural network to discard low surface quality fruit in packing plants. In this system author used VGG, ResNet and YOLO to classify different types of apple defects like wounds, rot and sunburn. The dataset of apple images was collected and labeled to train the particular models. In the middle of tested models, the modified ResNet101 achieved the highest accuracy of that is about 95% in detecting damaged or spoiled apples and this system can helpful for inspecting fruit quality in packing industries.

[8] Nikita Stasenko and et.al, described Deep Learning for improving the storage process: Accurate and automatic segmentation of spoiled areas on apples. This research is on automatic detection of spoil in apple fruit using AI and computer vision techniques and researcher developed the system that identify damaged areas on apples. To achieve this, they used deep learning module that is CNN for color, texture and shape for images segmentation modes. They were used U-Net and DeepLab to detect the exact spoiled regions on apples also used YOLO to classify Apple fruit as healthy or spoiled. They also train large dataset of apple fruit for helping to automate fruit quality inspection and reduce food waste in agriculture and food industries.

[9] Mudasar Iqbal and et.al, investigated Canned Apple Fruit Freshness Detection Using Hybrid Convolutional Neural Network and Transfer Learning. They introduced a framework for detecting the freshness of canned apples and used digital image processing, X-ray imaging and CNN with transfer learning. The system classifies apples into different parts like fresh, semi-fresh and rotten categories, gaining 98% accuracy and improving automated fruit quality inspection.

[10] Li Sun and et.al, suggested an improve CNN –based method for apple appearance quality classified using SVM for image segmentation, DCGAN for data augmentation and an improved ResNet50 model for classification. The Designed approach achieved 96.5% accuracy and that is good and demonstrating better performance even with a small dataset.

[11] Yanfei Li and et.al, developed Apple quality identification and classification by image processing based on convolutional neural networks. In this research they developed a CNN-based model for apple quality identification and classification using real images with complex backgrounds. The researcher developed deep learning model that compared with Google inspection v3 and traditional feature extraction methods such as HOG, GLCM and SM and achieved 95.33% classification accuracy. Exhibiting improved performance for automatic apple quality grading.

[12] Deepali M Bongulwar and et.al, described Evaluation of CNN based on Hyperparameters to Detect the Quality of Apples in this research they employ a CNN architecture, which is trained on two different parts first one is: Fruits Fresh and Rotten (Dataset1) with 1,693 fresh and second one is 2342 rotten apples used large dataset FruitsGB (Dataset2)

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with 1,000 good and 1,000 bad apple images. The CNN model utilized hyperparameter tuning including optimizers Stochastic Gradient Descent with Momentum and Adaptive Moment Estimation (optimizer) learning rate, batch size and number of epochs to maximize classification accuracy. SGDM optimizes performing best showing that CNN effective for fast, reliable and cost saving automated apple sorting.

[13] Seerat Un Nisa and et.al, described Image-Based Apple Diseases Detection Using Advanced Machine Learning Models. In this research they focus on apple disease image-based technique and ML and also DL models. The goal is to improve the speed, accuracy and scalability of detection in apple which traditionally relies on slow and error-prone for manual inspection. Collected studies that used Machine learning and Deep learning for apple disease detection and focuses methods like feature extraction techniques, CNN and SVM also Transfer learning approaches.

III. PROBLEM STATEMENT

In all the studied research, most of the researchers work on CNN based image processing algorithms for automatically analyzing apple images to detect quality, classify types, also identify diseases, making grading and sorting faster and more reliable. All the researchers explain various methods of apple quality detection. But there is lack of research in real time apple quality detection with higher accuracy. In this proposed research, CNN is used with GLCM and LBP method for determining the quality of the apple.

Research Objectives:

In the present research, the main goal is an early detection of spoilage on apple fruit and the workflow of the system will be proceeded by the following sub-objectives.

1) To collect the dataset for the healthy and spoiled apples.
2) To arrange the dataset as 80:20 pattern for training and testing the model.
3) To apply the CNN algorithm with GLCM and LBP method.
4) To Evaluate the model.

IV. METHODOLOGY

The aim of the present research is to analyze and classify an apple image using image processing and machine learning tools such as Convolutional Neural Network (CNN), Gray Level Co-occurrence Matrix (GLCM) and Local Binary Pattern (LBP) were employed to extract features and perform accurate classification. LBP is Local Binary Pattern used for texture feature extraction in images and it works like for each pixel. Comparing its intensity with its neighboring pixels there have usually 8 neighbors it assigns a value that is 1 if the neighbor is greater or equal to the center pixel, otherwise its show 0. It is presented in Binary form (Like,1010110001) for each pixel. after that the binary number are converted into histogram which represent the texture of the particular images. It helps for Apple Quality to detect surface patterns, spots or roughness that is easy to differentiate healthy vs spoiled. In other hand GLCM is also very helpful in the research for texture analysis method, focusing on spatial relationships between pixel intensities. it works very practically like analyze how often a pair of pixel intensities (gray levels) appear together at a certain distance and angle it represents. It means like find relation between (i, j) it represents the frequency of gray level i occurring next to gray level j. Statistically it works like four parts

1. Contrast – difference between neighboring pixel intensities
2. Correlation – how correlated pixel intensities are
3. Energy – uniformity of the texture
4. Homogeneity – smoothness of the texture. In Apple fruit detection it works on patterns like spots, lesions, or rough areas that indicate decay or disease.

Although the dataset for the present research was collected from accessible available source as well as from Kaggle source. The main part of the research that plays an important role is the image processing. It helps to detect quality and consistency of the dataset before feature extraction method and classification method. Initially all collected images

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were resized to a uniform dimension to maintain consistency across the dataset and reduce computational overhead. Detection, tracking and filters is the main work of OpenCV that is used for read, display, edit images, resize, crop and rotate the filters and sharpen for detection. Here OpenCV used for uneven size of images because model need uniform images for improve training speed and consistency. Gray Level Co-occurrence Matrix (GLCM) used for extracting the texture from images the features like they detect is contrast, correlation, energy and homogeneity. This is the statistical method where focus the relationship between pixel pairs and its work on global texture area. In short, its look at overall texture example. Another method used in this research is Local Binary Pattern (LBP) it's beneficial for small texture (like defect and changes) analyze and identify surface patterns like smoothness, roughness, edges and spots in an image also to convert an image into useful patterns that a model can understand. The final step is done by Convolutional Neural Network (CNN) that use all over for classifies the images its automatically extract features from images and classify them into different categories they work on to learn patterns such as edges, texture and shapes. This all features accurately classify the images also reduces image size it helps in faster processing and actually it has less computational tool it converts 2D into 1D that is the way which helpful for understanding and show final output that is spoiled or healthy.

Dataset

The dataset used in this research for the study of the apple images divided into two parts healthy and spoiled. To enable effective classification the images were collected from online sources like Kaggle. The dataset includes various variations in texture, lighting, background, color, condition texture to ensure diversity and improve the robustness of the model to improve performance and insure accurate classification. Healthy apple represents the normal surface condition, while spoiled apple represent some different surface condition include visible defects such as spots, discoloration and decay.

Healthy Spoiled

Fig.1 Healthy and Spoiled fruit

Dataset is the first important step in the research because its useful for train and test the model. Without training the data model cannot understand anything, the training data is used to teach the model, although CNN learns pattern from this data and evaluation is testing which is the second step after training. It checks the performance of the data and tells how well the model perform on new or unseen images its show real accuracy. Preprocessing done after dataset creation it's helping to resize the uploaded images this is very important part before CNN use because of images are not in same shape or size therefore it's very difficult to identify each fruit that is healthy or not so here applied simple code that is

image = cv2.resize(image, (img_size, img_size))

it's given proper result means resize all uploaded healthy and spoiled apple images

Feature shape: (489, 30)

Model Parameters of the CNN

The model parameter summaries of the CNN model are presented in Table 1. The model consists of a total of 7,396,418 parameters, that all which are trainable. This shows that the model learns all weights during the training process. There are no non-trainable parameters, which means no layers are frozen. The total model size is approximately 28.22 MB,

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reflecting the computational complexity of the network. After that training start the model, trained for 20 epoch its means it trains 20 time on given data for perfection that mean an epoch refers to one complete iteration over the entire training dataset, allowing the model to learn patterns and adjust its weights gradually to improve performance.

Table 1 Parameters of the CNN

Model: "functional"

Layer (type)	Output Shape	Param #	Connected to
input_layer (InputLayer)	(None, 128, 128, 3)	0	-
conv2d (Conv2D)	(None, 126, 126, 32)	896	input_layer[0][0]
max_pooling2d (MaxPooling2D)	(None, 63, 63, 32)	0	conv2d[0][0]
conv2d_1 (Conv2D)	(None, 61, 61, 64)	18,496	max_pooling2d[0]…
max_pooling2d_1 (MaxPooling2D)	(None, 30, 30, 64)	0	conv2d_1[0][0]
flatten (Flatten)	(None, 57600)	0	max_pooling2d_1[…
input_layer_1 (InputLayer)	(None, 30)	0	-
concatenate (Concatenate)	(None, 57630)	0	flatten[0][0], input_layer_1[0]…
dense (Dense)	(None, 128)	7,376,768	concatenate[0][0]
dense_1 (Dense)	(None, 2)	258	dense[0][0]

Total params: 7,396,418 (28.22 MB)
Trainable params: 7,396,418 (28.22 MB)
Non-trainable params: 0 (0.00 B)

Epoch 1/20
13/13 ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 11s 705ms/step -accuracy: 0.5499
- loss: 2.2233 - val_accuracy: 0.4898
val_loss: 0.8199 Epoch 2/20
13/13 ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 11s 826ms/step accuracy: 0.6138
- loss: 0.7362 - val_accuracy: 0.6531 - val_loss: 0.5828 Epoch 3/20
13/13 ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 18s 681ms/step - accuracy: 0.7673
- loss: 0.5090 - val_accuracy: 0.7857 - val_loss: 0.4440

Above iterations shows how actually model shows that epoch work. After training how many healthy and spoiled fruit are available in dataset shows with the help of accuracy graph model accuracy is used to evaluate the performance of the classification model, here is then try to find loss and accuracy of the test data then this result occurs.

4/4 ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1s 132ms/step - accuracy: 0.9490 - loss: 0.2447
Test Accuracy: 0.9489796161651611

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V. RESULTS & DISCUSSION

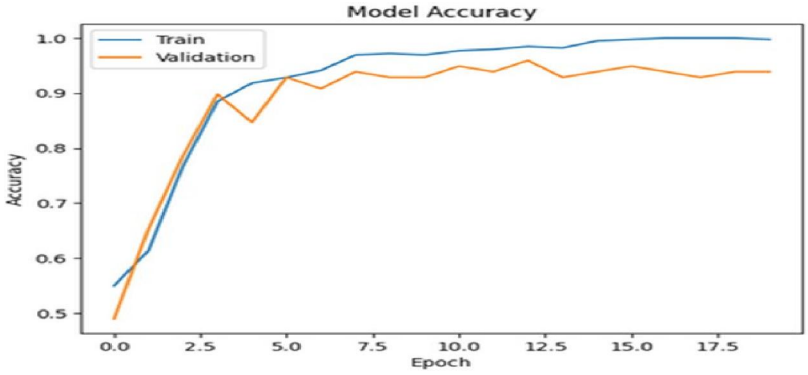

Fig. 2 Model Accuracy

The Fig.2 shows the model accuracy graph for training and validation of the apple dataset. The accuracy graph shows that the training dataset and validation dataset accuracy is nearly close to each other. It means that the model trains the data with 94% accuracy as well as the model validate the data or test the data is near about the training accuracy. It means model detects the images with high accuracy and minimum loss. It also shows that the model effectively works on the classification of the spoiled apple and healthy apple.

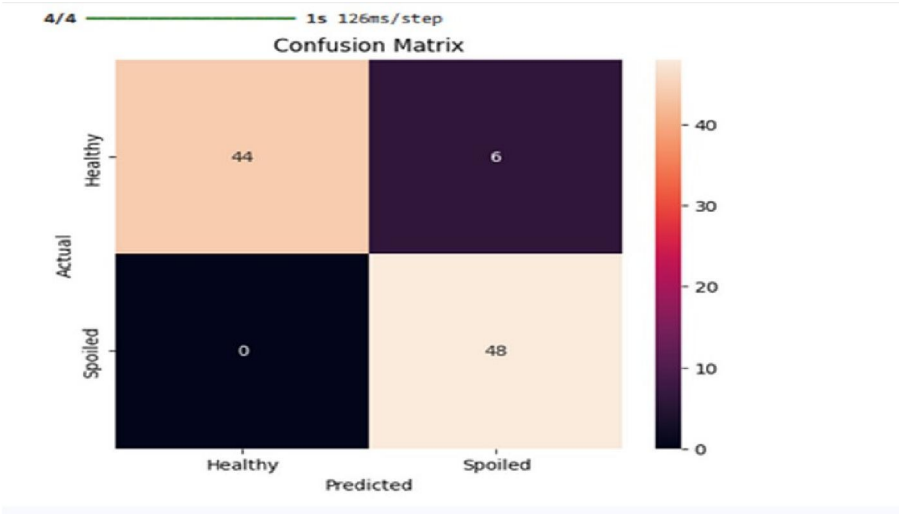

Fig.3 Confusion Matrix graph

The above graph shows the confusion matrix which predicted healthy and spoiled apple. The graph clearly shows that the predicted true images of healthy and spoiled is truly correct and minimum false values of the predicted images. The Table 2 shows the precision, recall, f1-score of the tested images of the healthy and spoiled apples.

Table 2 Tested image score

	precision	recall	f1-score	support
Healthy	1.00	0.88	0.94	50
Spoiled	0.89	1.00	0.94	48
accuracy			0.94	98
macro avg	0.94	0.94	0.94	98
weighted avg	0.95	0.94	0.94	98

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VI. CONCLUSION

The present research goal is early detection of spoiled fruit using CNN with GLCM and LBP method. The system detects the spoiled apples early which are totally invisible for the human eyes. For developing this system CNN algorithm with GLCM and LBP method employed. By employing such methods, the system gives high accuracy with minimum loss. It works very well in classification of the spoiled apples and healthy apples. The system analyzes the texture of the apple which gives the early warning for the spoiled apples. The present system gives 94% of training and validation accuracy and by confusion matrix it predicts very well the image accuracy. The system employed GLCM and LBP which works best as compared to other algorithms and methods.

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