IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 2, September 2023

Grading of Pomegranate Fruit using CNN

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Abstract: *Farmers require an automated system to grade Pomegranate fruits rather than a manual system to increase productivity and quality of Pomegranate fruits. Manual grading of fruits does not produce adequate results and requires additional time for disease identification and gradation, as well as the expertise of an expert, making it ineffective. The suggested system is an efficient module that identifies various pomegranate fruit disorders and determines the stage of sickness. Effective growth stage monitoring and disease detection are critical for maximising pomegranate fruit yield and quality. This paper describes a method for monitoring the growth stages of pomegranate fruit utilising image processing techniques and disease detection approaches based on machine learning algorithms. The suggested method analyses colour, shape, and texture information taken from photos captured at various phases of development to track the growth stages of pomegranate fruit. The obtained data is then utilised to train machine learning models that appropriately distinguish the growth stages. The models are trained on a dataset of annotated photos containing numerous pomegranate fruit illnesses. Farmers and agricultural specialists can use the developed technology to correctly monitor the growing phases of pomegranate fruit and detect problems. The camera in this project catches various pomegranate fruit stages and classifies pomegranate fruits into two classes: infected and non-infected, using a machine learning algorithm and Python tools. This study employs a CNN, K-mean method, and image processing technique to detect illnesses at various phases of fruit development.*

Keywords: Pomegranate, image processing, CNN, Python, Diseases, fruit grading

I. INTRODUCTION

India is one of the world's largest pomegranate growers. In today's world, getting high-quality products, whether agricultural or otherwise, is difficult. In the market, excellent quality commands a greater price. Maintaining high quality in agriculture is a difficult endeavour[1-5]. India is the world's second largest producer of pomegranate fruit. Fruit quality assessment is the most crucial activity in post-harvesting stages before shipping them to market to get a better price since quality fruits bring greater profit to farmers. When done by people, quality examination of fruits takes time. As a result, fruit grading is done using an automated method. This project introduces a Python-based system in which we focus on fruit diseased areas, fruit spots, fruit colour, and applied image processing techniques to determine fruit quality accurately and quickly during the post-harvesting stage[6-12].

Stage infection is one of the most important factors that reduces and lowers the quality of agricultural products. Fruit infections are becoming more widespread during the growing stage, as elements such as climate and environmental circumstances are more volatile than ever[13-19]. The image processing process begins with the capture of digital high-resolution images. Captured photos are saved for future use. The image is then pre-processed for image enhancement and the symptoms of two diseases at various stages are listed here[20-25].

DISEASES-

- BACTARIAL BLIGHT-Bacterial Blight is a dangerous disease that causes blemishes and lesions on pomegranate fruit. Bacteria can enter the body through wounds or natural holes and spread quickly. Fruits that have been infected acquire dark, sunken patches, and in severe cases, they may fracture or split apart. Pruning infected branches, using copper-based sprays, and practising excellent cleanliness are all effective control techniques. Figure 1 shows some photos of bacterial blight[26-30].

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- FRUIT ROT - Fruit rot is a post-harvest disease caused by the fungus Aspergillusniger. It has an impact on pomegranate storage and shipping. Fruits infected acquire black, sunken blemishes with a powdery look. Proper harvesting and handling practises, as well as proper storage conditions, can help analysis. Fruit rot can be reduced by using proper harvesting and handling practises, as well as adequate storage conditions. Figure 1 shows some photos of fruit rot[31].
- Alternaria Fruit Spot- Alternaria fruit spot is characterised by the development of dark coloured lesions on pomegranate fruit. These lesions are frequently circular and may resemble a target with concentric rings. Lesions develop sunken and may generate spores as the disease proceeds, giving them a powdery appearance. Rotting can spread throughout the fruit in severe cases[32].

Figure 1 shows the different infection on fruit.

Fruit rot disease **Bacterial blight disease**

Fig 1- Diseases of Pomegranate fruit

Common pomegranate growing stages -

The various stages of pomegranate fruit growth are explained below, and some sample photographs of pomegranate fruit stages are provided in fig no.2.

- The blooming stage: This is the beginning of fruit growth. Pomegranate trees have beautiful, colourful blossoms that are usually orange-red in colour. Male (stamens) and female (pistil) reproductive components are found in the flowers. Insect pollination, particularly by bees, is critical for fruit set success[33].
- Fruit Set: Pomegranate flowers begin to develop into little fruits after successful pollination. The pollinated flowers' ovaries begin to enlarge, generating small green fruit capsules. Proper irrigation, nutrition, and pest management practises are critical at this period to guarantee optimal fruit development[34-37].
- Fruit expansion: As the fruit capsules expand, they go through a rapid growth and expansion period. The fruit begins to grow in size and colour, changing from green to yellow or pink depending on the pomegranate variety. This is an important stage for fruit development, and appropriate sunshine, water, and nutrients are required for maximum growth[38-40].
- Fruit Maturation: The pomegranate fruit continues to expand and undergoes physiological changes during this stage. The colour of the fruit intensifies, and it becomes firmer and more glossy. Sugars and other substances collect in the fruit, contributing to its flavour and scent. The maturation time varies by pomegranate type and can take anywhere between 4 and 7 months after fruit set.
- Harvesting: The harvesting of pomegranate fruit depends on the desired maturity level and the variety. Pomegranates are typically harvested after the fruit has achieved full size, the colour has fully matured, and the texture is firm. Too early harvesting can result in immature fruits with low flavour and quality.
- Post-Harvest Ripening: If stored properly, pomegranates can continue to ripen after harvest. During this post-harvest ripening period, the fruit continues to develop in colour, softness, and flavour. Pomegranates should be stored in a cool, well-ventilated environment to prevent rotting and maintain quality.

Understanding the stages of pomegranate fruit growth allows growers to make informed decisions about irrigation, fertilisation, pest management, and harvesting to maximise fruit yield and quality. It's also worth noting that the time and characteristics of each growth stage may differ based on the pomegranate variety, environment, and growing conditions.

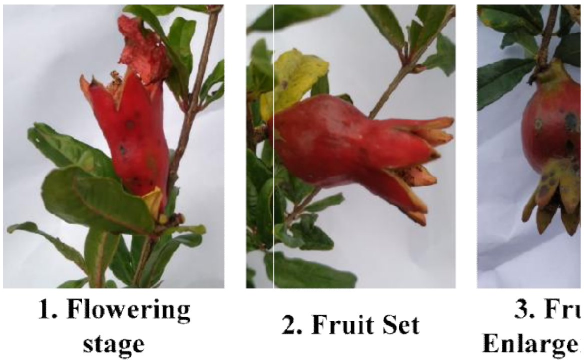

Fig. 2 – Stages of development of fruit

II. PYTHON SUMMERY

Python is a high-level programming language noted for its ease of use, readability, and versatility. It was initially released in 1991. Python has grown in popularity among developers, data scientists, and researchers because to its rich libraries, ease of use, and wide range of applications. Python's key traits and features include readability, ease of learning, cross-platform compatibility, a big standard library, extensive third-party libraries, object-oriented programming, dynamic typing, an interpreted language, a community, and support[41-44].Python's adaptability allows it to be used for a wide range of applications, including web development, scientific computing, data analysis, machine learning, artificial intelligence, automation, and others. Because of its extensive libraries and community support, it is an excellent candidate for applying image processing techniques in fruit gradation. . Python's image preprocessing, feature extraction, machine learning, and visualisation capabilities enable rapid and precise fruit gradation analysis, assisting in quality control and decision making in the fruit sector. For image processing in fruit image recognition, Python is frequently favoured over MATLAB[45-50] for numerous reasons:

Python is an open-source programming language, which means it is freely available for use and modification by anybody. MATLAB, on the other hand, requires a paid licence, which makes it less accessible to some people. Because Python is open-source, researchers and developers can freely use and contribute to a large range of image processing modules and tools.

- Extensive Libraries: OpenCV, scikit-image, and NumPy are just a few of the powerful tools and frameworks available in Python for image processing. Python is a viable solution for fruit image identification jobs since these libraries provide a wide range of methods and techniques for picture editing, feature extraction, and object detection. Python has a big and active community of developers, academics, and users, as well as extensive documentation. This active community provides substantial documentation, tutorials, and online tools to help newcomers learn and troubleshoot image processing jobs. Although MATLAB has a sizable user base, the Python community is more diversified and ubiquitous.
- Integration with Other Technologies: Python works well with other technologies and platforms. It can function in tandem with machine learning frameworks (such as TensorFlow and PyTorch), web development frameworks (such as Django and Flask), and big data processing tools (such as Apache Spark). This adaptability enables image processing algorithms to be easily integrated into bigger workflows and systems. Python’s simplicity and readability make it a great language for rapid prototyping and development. Its syntax is simple and intuitive, making it easy for academics and developers to create and test various image processing approaches. While MATLAB is well-known for its mathematical capabilities, it can be less versatile and slower when it comes to rapid prototyping and development.

While MATLAB remains popular in particular sectors, such as academics and specific businesses, Python's versatility, accessibility, and broad ecosystem have made it a popular choice for image processing jobs, such as fruit image detection.

III. LITERATURE REVIEW

Various studies are being conducted around the clock on the subject of post-harvest grading of various agricultural and horticultural products. Lee et al. (2008) introduced a novel method for evaluating the quality of fruits. Colour quantification and colour analysis techniques have been used to assess the quality of fruits. K.D. Babu, R.A. Marathe, and V.T. Jadhav. Pomegranate post-harvest management. ICAR National Pomegranate Research Centre, Solapur, India. An overview of an image processing approach for grading and identifying illnesses on pomegranate fruit. The other gathers photographs from the national pomegranate research centre in Solapur, Maharashtra, India. Filtering and segmentation are applied to these photos once they have been pre-processed. V. G. Narendra and K. S. Hareesha. 2011. Colour traits are used to classify cashew karnels. International Journal of Machine Intelligence 3(2):52-57. A new technique for automatic monitoring of fruit stages and fruit grading was developed, and encouraging results were obtained. The pomegranate plats used were from the variety, which is the most extensively farmed in Spain. They were grown on a plantation owned by the Valencia Polytechnic University, which is located within the municipal boundaries of Alicante.

Arun Kumar R and Vijay S Rajpurohit published in IEEE in 2017. The pomegranate fruits in the image dada set were obtained from a local fruit market. The images are then preprocessed before being put into a feature extraction programme. There are two types of extracted features: spatial domain features and wavelet features. The sorting procedure has been completed, and the findings have been analysed. The work has only a few constraints. The author considered a vast number of features, all of which are not used in the grading procedure. The various stages of fruit growth and development between winter dormancy are described using fleckinger's (1945) typical technique, in which the general stages are named.

Because research on pomegranate fruit growth stages and grading is limited, there is more opportunity to conduct research on pomegranate fruit growth stages and grading assessment. This is also consistent with the industrial applications of pomegranate fruit sorting. As a result, the current work aims to establish monitoring and automation of fruit growth stages in order to improve grade based on illnesses, colour, and size.

IV. METHODOLOGY

The suggested technique intends to model fruit growth observation and checking the condition, illness detection, and grading for pomegranate fruit based on diseases, colour, and size. The system employs a variety of image processing techniques, including pre-processing, segmentation, and feature extraction, as well as Python libraries. As an input for our work, we employed a pomegranate fruit dataset that detects or identifies illnesses at various fruit stages. We use Python to create a CNN model, which includes a training data set. The train dataset is made up of infected and non-infected fruit. Figure 3 depicts the block layout of the proposed system[51-55].

4.1 Dataset Preparation

Creating a dataset for monitoring the growth phases of pomegranate fruit and illness detection. Pomegranate trees are vulnerable to a variety of illnesses that can harm the fruit. Fruit illnesses that are common include bacterial blight, fruit rot, alternaria fruit rot, and others. We collect a variety of fruit photographs featuring non-infected pomegranate fruits as well as fruit images representing various disease situations that indicate infection. These fruit photos span a wide range of diseases, severity levels, and phases. The dataset was divided into training and testing sets. The training dataset is used to train the model, whereas the testing set is used to evaluate the model's ultimate performance. Figure 3 depicts a variety of photos from the dataset. Table No.1 exhibits dataset attributes from a pomegranate fruit dataset that focused on features such as fruit colour, size and shape, and fruit spot.

Fruit stage with no fruit fruit Colour fruit Shape -
1 to 8 Fruit maturity Brownish black on a regular basis
2 0 Fruit assortment Pale yellow on a regular basis
3 4 Flowering Orange on a regular basis… …. …. …. ….
900 -1 Fruit assortment Fruit enlargement
998 5 Regular orange Pale yellow on a regular basis

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Table 1- Attributes from a pomegranate fruit dataset

No	Fruit Spot	Fruit stage	Fruit Shape	Fruit Color
1	8	Fruit maturity	Regular	Brownish black
2	0	Fruit set	Regular	Pale yellow
3	4	Flowering	Regular	Orange
…	….	….	….	….
900	1	Fruit set	Regular	orange
998	5	Fruit enlargement	Regular	Pale yellow

4.2 System Operation

In the agriculture industry, several computerised tools and sensors such as temperature sensors, humidity sensors, leaf wetness sensors, and so on have been created to assist farmers in crop monitoring. In this paper, we describe a new technique for monitoring and automating the fruit growing stage in order to improve grade based on illnesses, size, and colour. The system can be used to solve the manual monitoring and grading problem. Image acquisition, feature extraction, monitoring, and disease detection are all part of the system's three processes.

The use of computer algorithms to perform image processing on digital images is known as digital image processing. Digital image processing, as a subcategory or field of digital signal processing, has significant advantages over analogue image processing. It enables the application of a much broader variety of algorithms to the input data and can avoid issues such as noise accumulation and signal distortion during processing.

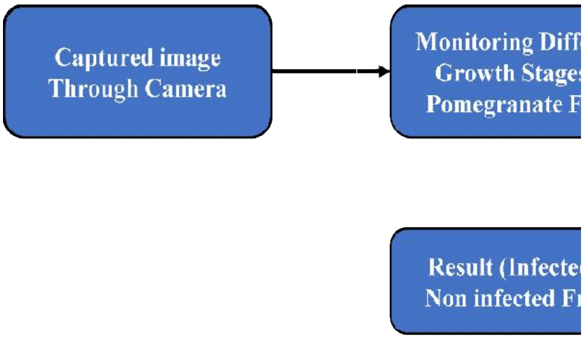

Fig 3: Proposed Work System

Various techniques were used to measure four quality features: colour, spot, shape, and size. Figure 1 depicts the general method to image processing. The proposed system produces satisfactory findings and can be further developed for agricultural product analysis. The project's working system is outlined below:

- **Camera-**Digital cameras are commonly used for picture capture. Capturing images with an image sensor, often a charge-coupled device. The taken image is then saved digitally in a format like JPEG or RAW. The initial stage in our approach is to capture the photograph. We use a camera to capture several stages of pomegranate fruit such as flowering, fruit set, fruit enlargement, and fruit maturity[56].
- **Choosing a Model** Several machine learning methods can be used to detect fruit illnesses. The selection of algorithms is influenced by aspects such as problem difficulty, dataset quantity and quality. Convolutional neural networks, support vector machines, K-nearest neighbours, deep learning architectures, and so on are examples of deep learning architectures. These are some of the most regularly used machine learning algorithms for detecting pomegranate fruit illnesses. In our project, we use the CNN model[57], which is frequently used for image classification tasks such as detecting fruit illnesses. CNNs are specifically built to learn and extract relevant features from images automatically.
- **Evaluating model performance**- Assess the trained model's performance in disease classification and grading on the testing set. To assess the model's effectiveness in illness detection and pomegranate fruit gradation, compute metrics such as accuracy, precision, recall, and F1-score[58].

- **Output** is the final stage in our planned work flow. In the end, we had both infected and uninfected pomegranate fruit. Non-infected pomegranate fruit is classed as having three diseases: bacterial blight, fruit rot, and fruit spot.

Flow Diagram is shown in figure 4.

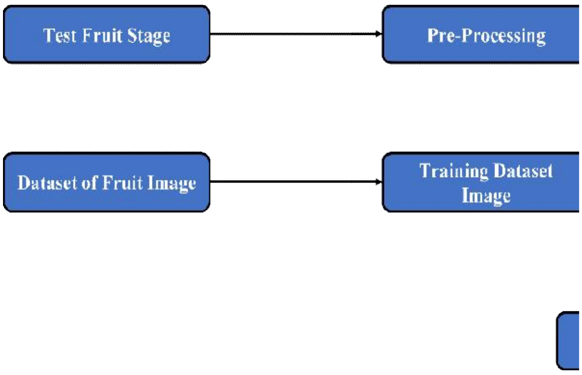

Fig 4: Flow Chart

Image Pre-processing:

The first stage in analysing photos for illness diagnosis is image pre-processing[59]. It employs a number of strategies to improve the image's quality and make it suitable for further examination. Some common pre-processing procedures for detecting fruit disease include:

a) *Image resizing*: Resizing the image to a standardised resolution aids in the normalisation of the input and ensures consistency in following processing steps[60].
b) C*ropping*: Cropping the photograph to remove extraneous background or irrelevant elements aids in focusing on the fruit and sickness symptoms.
c) *Image normalisation:* Normalising image intensities across multiple channels (for example, RGB channels) helps to reduce variances caused by lighting conditions.
d) *Noise removal:* Using filters like Gaussian blur or median blur can assist reduce noise in an image, making it easier to extract important features.
e) *Colour space conversion:* Converting an image to a different colour space (e.g., RGB to HSV or LAB) might help with specialised disease detection tasks by separating colour information that is related to disease symptoms.

Segmentation:

The process of dividing a picture into relevant sections or segments is known as segmentation[60]. Segmentation is used in fruit disease detection to separate the fruit from the background and isolate disease-affected patches. In this context, several segmentation approaches are used:

a) T*hresholding*: Using a threshold to segregate pixels based on intensity or colour values in a picture. This technique can be useful when illness symptoms differ in colour or intensity from healthy fruit.
b) *Region-based segmentation*: Identifying regions based on texture, colour, or intensity features that are similar. When disease symptoms exhibit textural variations or distinct colour patterns, this technique can be effective.
c) Detecting the edges or boundaries of items in a picture. It can aid in distinguishing between the fruit and disease-affected parts.
d) *Watershed segmentation:* Separating related regions using the notion of water flow. It can be used to divide neighbouring fruits or distinct disease-affected areas.

V. EXTRACTION OF CHARACTERISTICS

The process of obtaining useful information or characteristics from segmented regions is known as feature extraction. These qualities serve as distinguishing characteristics between healthy and unhealthy fruit. Fruit disease detection characteristics commonly employed include:

a) Colour features: Extracting color-related data from segmented regions, such as mean colour values, colour histograms, or colour moments.
b) Texture characteristics: Extracting texture-related features from segmented regions, such as local binary patterns (LBP), gray-level co-occurrence matrix (GLCM), or Gabor filters.
c) Shape characteristics: Extracting shape-related features from segmented regions such as area, perimeter, compactness, or eccentricity.
d) Statistical characteristics: Extracting statistical features from segmented regions such as mean, standard deviation, or skewness of pixel intensities.
e) Deep learning features: Obtaining features using pre-trained deep learning models, such as convolutional neural networks (CNNs), that have been trained on large-scale picture datasets.

Once the essential features have been retrieved, they can be fed into classification algorithms to determine the prevalence and severity of fruit illnesses.

Overall, the combination of image pre-processing, segmentation, and feature extraction approaches is significant in fruit disease detection because it allows for accurate identification and analysis of disease-affected regions in fruit images.

VI. CLASSIFICATION

Create a CNN model that can classify fruit images. Convolutional layers for feature extraction, pooling layers for down sampling, and fully linked layers for classification comprise the model. To boost the diversity of the training dataset, use data augmentation approaches. Techniques such as rotation, scaling, flipping, and random cropping can be used. Rotation, scaling, flipping, and random cropping are all techniques that can be employed to generate more training examples and improve the model's robustness. Using the training dataset, train the CNN model. During training, optimise the model's parameters with an optimizer and an appropriate loss function, such as binary cross-entropy. Monitor the model's performance on the validation set and make any necessary adjustments. Deploy the model for real usage once it has demonstrated adequate performance.

VII. CONCLUSION

Using image processing and the Python programming language, we are monitoring distinct growth stages to improve grading of Pomegranate fruits. In the fruit grading process, computer vision and image processing algorithms produce non-destructive and accurate results. Image segmentation, feature extraction, and other approaches are used to monitor fruit growth and improve grading. Depending on the characteristic, each offers pros and downsides. CNN architecture is used to classify or identify whether pomegranate fruit is infected or not. The ongoing development of various technologies in pomegranate fruit disease detection and grading offers significant potential to improve their decision-making capabilities and contribute to the agriculture industry's long-term growth. This finally helps farmers in their everyday battle against disease outbreaks. Once the disease and its stage are correctly identified, the farmer may treat it properly with the assistance of experts. The future scope for pomegranate fruit disease detection and grading for farmers includes developing userfriendly mobile applications that let farmers to shoot photographs of pomegranate fruit using their smartphone. Farmers investigate the health of their pomegranate fruit and make decisions or take urgent action based on diseases discovered. These proposed systems would encourage Indian farmers to practise smart farming, which allows them to make timely decisions, saving time and reducing fruit loss due to illness. Farmers will benefit from image processing techniques and the Python system.

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