



International Journal of Agriculture Innovation, Technology and Globalisation

ISSN online: 2516-1970 - ISSN print: 2516-1962
<https://www.inderscience.com/ijaitg>

Fruit disease detection using colour, texture and ANN: a sustainable approach for smart cities

Rohit Rastogi, Prateek Singh

DOI: [10.1504/IJAITG.2024.10067062](https://doi.org/10.1504/IJAITG.2024.10067062)

Article History:

Received:	06 January 2024
Last revised:	13 January 2024
Accepted:	30 April 2024
Published online:	11 October 2024

Fruit disease detection using colour, texture and ANN: a sustainable approach for smart cities

Rohit Rastogi* and Prateek Singh

Department of CSE,
ABES Engineering College Ghaziabad,
UP, India
Email: rohitrastogi.shantikunj@gmail.com
Email: prateeksingh6125@gmail.com
*Corresponding author

Abstract: Timely and precise identification of fruit disease is crucial for preventing yield losses and ensuring crop quality. The purpose of this research focuses on the integration of colour texture analysis for automated detection using artificial neural networks (ANN). The combination of colour and texture features provide a comprehensive approach for visual characteristics of fruit surfaces, enhancing the accuracy and robustness of disease detection system. The proposed framework involves the following key steps: image acquisition, pre-processing, feature extraction, and classification using ANN. High-resolution images of fruit surfaces are captured using digital cameras or other imaging capturing devices. Pre-processing techniques including noise reduction and image enhancement are applied to ensure the quality of input data. The visual attributes of a fruit are represented through the computation of colour and texture features using methods like local binary patterns or grey level co-occurrence matrix. The study uses feature vectors to train an ANN to identify and classify fruit diseases based on colour and texture information.

Keywords: artificial neural networks; ANNs; training data; learning algorithms; classification metric; precision; agriculture; Python; OpenCV; TensorFlow; PyTorch; data augmentation; explainable AI; XAI; HTML; CSS; JavaScript; Streamlit.

Reference to this paper should be made as follows: Rastogi, R. and Singh, P. (2024) 'Fruit disease detection using colour, texture and ANN: a sustainable approach for smart cities', *Int. J. Agriculture Innovation, Technology and Globalisation*, Vol. 4, No. 1, pp.63–96.

Biographical notes: Rohit Rastogi received his BE in CSS University Meerut, 2003, and Master's in CS of NITTTR-Chandigarh from Punjab University. He received his Doctoral degree from the Dayalbagh Educational Institute in Agra, India. He is serving as an Associate Professor in the CSE Department of ABES Engineering College, Ghaziabad, India. He has won awards in several areas, including improved education, significant contributions, human value promotion, and long-term service. He keeps himself engaged in various competition events, activities, webinars, seminars, workshops, projects and various other educational learning forums. He has guided around 60 BTech students' projects and five MTech theses. He is an editor and reviewer member of several international journals and conferences. He has 100+ publications in journals and conferences of international repute. He strongly believes that transformation starts within self.

Prateek Singh is an engineering student in Computer Science at the ABES Engineering College, Ghaziabad, Uttar Pradesh, India. He has been keenly interested in coding and open-source projects. His hobbies are playing basketball and reading books. His wish is to be a successful software engineer and to serve his knowledge to the nation.

1 Introduction

1.1 Evolution of fruit disease detection system

The evolution of a fruit disease detection system involves the development and enhancement of various technologies, methodologies, and capabilities over time. Traditional methods include visual inspection, which is subjective and may lack accuracy. Early technology adapt includes basic image processing techniques, which are then integrated with colour and texture analysis. Machine learning approaches, such as decision trees or support vector machines (SVMs), are introduced to enhance disease detection proficiency. Deep learning and convolutional neural networks (CNNs) are used for image classification tasks, which can automatically learn hierarchical features. Multi-modal approaches combine information from various sources, such as colour, texture, and sensor data, to create a more comprehensive and accurate detection system. Edge computing and IoT integration are used for real-time processing of data and real-time monitoring and data collection from multiple agricultural sources. Cloud-based solutions and big data analytics are implemented for scalable and flexible processing. Autonomous systems and robotics are integrated for automated data collection, analysis, and targeted treatment application based on disease detection results. Artificial intelligence and continuous learning models are implemented, and human-AI collaboration is encouraged.

Explainable AI focuses on developing models that provide transparent and interpretable results, enabling users to understand the reasoning behind disease predictions. Global connectivity and data sharing are also integrated for improved global agriculture. The evolution of a fruit disease detection system is an ongoing process driven by advancements in technology, artificial intelligence, and agricultural challenges (as per Figure 2).

1.2 Current state of fruit management systems

The challenges in current fruit disease systems can be multifaceted and includes various factors related to detection, prevention, and management of the diseases affecting fruit crops. Fruit disease management faces several challenges, including limited early detection systems, data accuracy and integration, predictive models, rapid disease spread due to globalisation and trade, climate change impact, limited resources for small-scale farmers, pesticide resistance development, and lack of awareness among farmers, inadequate regulatory frameworks, and interdisciplinary collaboration. These issues can be addressed through technological advancements, research initiatives, awareness campaigns, and policy improvements. Accurate predictions and control measures are crucial for disease management, but balancing complexity with usability is a challenge.

Climate change can also alter traditional disease patterns, and limited resources can hinder effective disease management.

Figure 2 Fruit diseases (see online version for colours)

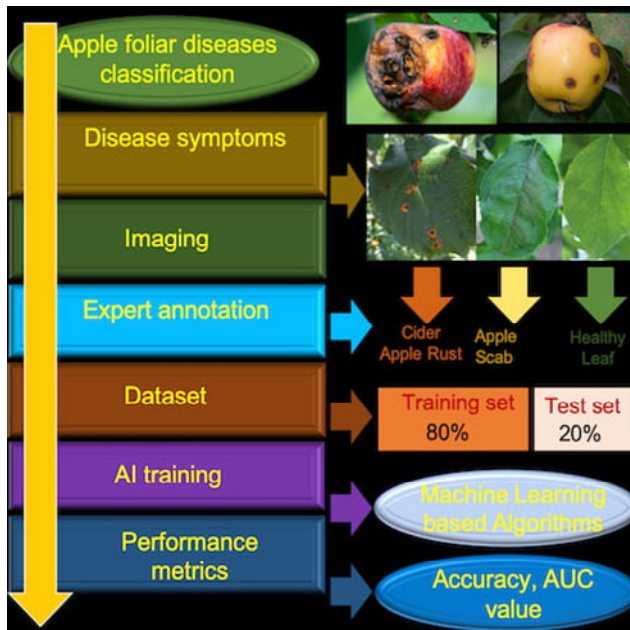


Source: <https://www.pantechelearning.com/product/fruit-disease-detection-using-image-procesing/>

The information provided in January 2022 does not provide specific details on the developments or changes in fruit disease systems for 2024 and the current method is not developed (as per Figure 3).

1.3 Introduction of fruit disease detection system in healthcare

The phrase ‘fruit disease detection system in healthcare’ may confuse you as it combines fruit diseases and healthcare. Fruit disease detection systems aim to identify and manage diseases affecting fruit crops in agriculture using technologies like sensors, imaging devices, and data analytics. Modern systems use techniques like remote sensing, image processing, machine learning, and IoT devices for early detection, classification, and monitoring of diseases. In healthcare, disease detection systems focus on identifying, analysing, and diagnosing diseases in humans using technologies like medical imaging, laboratory tests, wearable devices, and AI-based diagnostic tools. These systems help healthcare professionals identify diseases and formulate treatment plans through a detailed prescription, where a doctor can easily diagnose the disease by knowing the chemicals and the disease that are in it.

Figure 3 Current system format (see online version for colours)

Source: <https://blogs.cornell.edu/applevarietydatabase/machine-learning-for-disease-detection/>

The main goal is to implement more fruit disease detection machines in agricultural areas so the farmer can easily resolve them; otherwise, remove them from the field so they don't affect other fruit. In healthcare, the person has to know what is good and not to eat just by eating without knowing if it is infectious or not, which can cause a problem in the human body (as per Figure 4).

1.4 Rationale for integration and research objectives

Food security is a global concern, and integrating various technologies in fruit disease detection systems can help address these challenges. The integration of remote sensing, IoT, and machine learning can enhance the accuracy and reliability of disease detection, allowing for early detection and timely intervention. Multi-modal data fusion can provide a holistic view of plant health, enabling a more comprehensive understanding of the complex interactions between environmental factors, plant physiology, and disease dynamics. Synergistic information retrieval can improve system performance, support precision agriculture, and facilitate real-time monitoring and decision support. Integrated systems can adapt to diverse environmental conditions, ensuring they remain effective in various agricultural settings. Technological synergy and innovation can be fostered through collaboration between different technologies, leading to new tools and methods that can further advance fruit disease detection efficiency. Lastly, an integrated approach can offer economic benefits for farmers, such as improved crop yield and reduced input costs, demonstrating its practical applicability (Mehmood et al., 2023).

Figure 4 Fruit and healthcare (see online version for colours)

Source: <https://www.freepik.com/photos/healthcare-fruits>

Figure 5 IoT integrated machines (see online version for colours)

Source: <https://www.mdpi.com/2073-4395/13/6/1625>

The integration of technologies in fruit disease detection systems offers advantages such as accuracy, early detection, precision agriculture, real-time monitoring, adaptability, technological synergy, and economic viability. In the following figure, as you can see, there are different types of machines that are used to detect fruit disease (as per Figure 5).

Motivations

The impetus for this project arises from the urgent need to address various shortcomings in agricultural yield. Currently, there are machines available for quality checking, but their high expense may make them unaffordable for many farmers. Consequently, farmers might refrain from investing in such technology, potentially leading to the unintentional spread of diseases through the transportation of contaminated fruits to local markets. This poses a risk to both the crops and, subsequently, human health. Developing a cost-effective fruit disease detection system using colour, texture, and ANNs aims to provide a more accessible solution for farmers, enabling them to identify and manage diseases efficiently, thus mitigating risks associated with the spread of diseases and ensuring the production of healthier crops for consumption.

Research objectives

The primary goal of this project is to design, create and establish a fruit disease detection system which reduces the risk agriculture yield loss as well as preventing harmful disease. The system aims to prevent harmful diseases in fruit crops by detecting them early and accurately, empowering farmers with a proactive tool for timely interventions. This aligns with promoting sustainable agriculture and ensuring food safety for both farmers and consumers. So, we create a robust and effective fruit disease detection system that makes a significant impact on the agriculture sectors. The fruit disease detection system should be a collaborative and adaptive effort, involving experts in machine learning, computer vision, and agriculture.

A diverse dataset representing various fruits, diseases, and environmental conditions is essential for training a robust model. User involvement, real-world testing, and a feedback loop are crucial for ensuring the system's relevance and effectiveness. Scalability and adaptability are essential for the system's longevity. Open communication, ethical considerations, and comprehensive documentation are essential for troubleshooting and knowledge transfer. Long-term support and maintenance are also crucial for the system's effectiveness.

Scope of the work

The fruit disease detection project aims to improve crop management and reduce losses by detecting diseases in fruits. The project involves image processing and analysis, machine learning and ANNs, data collection and preparation, and user interface design. The system targets individual fruits because of regional significance and disease coverage, ensuring adaptability to new diseases. The project also considers the application of the system in different agricultural settings, considering climate, soil

conditions, and farming practices. Raining materials and support are also provided for end-users. Future considerations include scalability and adaptability to emerging technologies and advancements in machine learning. By defining the project scope, the project team can ensure the objectives align with goals of improving agricultural practices and food safety.

Role of authors

The authors collectively bring a diverse range of expertise and experiences vital to the concept, development, and realisation of this research. Dr. Rohit Rastogi led the conceptualisation and design phase, leveraging their extensive knowledge in fruit disease informatics and ANN technology. Mr. Prateek, as a machine learning and computer vision expert, led the technical implementation of a fruit disease detection system. He applied machine learning algorithms and computer vision techniques to analyse fruit images, designed an ANN for accurate disease classification, and enhanced the model's performance and participated in real-world testing and validation, ensuring the system's scalability and adaptability. To ensure comprehensive documentation and knowledge transfer. His role is crucial in the successful development of the system, contributing to the overall success in addressing agricultural challenges.

Deliverables

- 1 *User interface prototype*: A working prototype that demonstrates the use of ANN technology, classification of local data, make a secure and compatible user interface and the MERN stack for web applications development.
- 2 *Technical document*: An extensive detailed documentation that demonstrates the technical specification, including algorithm for colour and texture analysis. Neural network architecture and image processing.
- 3 *Research paper*: A research paper through which the details the project's aims, methodology, findings, and consequences.
- 4 *User guides and manuals*: These guides and manuals should be designed to be clear, concise, and accessible to their respective audiences, providing comprehensive support for users, administrators, and developers interacting with the fruit disease detection system.

Stakeholders

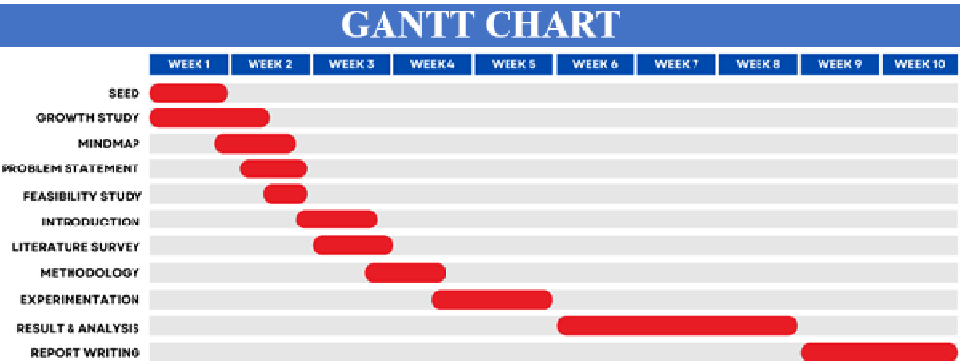
- *Farmers*: Early disease detection can protect crops and increase yield, benefiting users who provide feedback on its practicality and effectiveness in real-world farming scenarios.

- *Health authorities:* The task involves providing guidelines and regulations for the effective detection of diseases in fruits, ensuring they comply with health and safety standards for consumer protection.
- *End users (general public/consumers):* The system indirectly benefits from the quality of fruits available for consumption, ensuring access to safe and disease-free options in the market.
- *Educational institutions:* Contributing to research, development, and education in agriculture and technology, with involvement in collaborations, expertise, and training programs.

Gantt chart

The Gantt chart is a visual tool that shows the project timeline, illustrating tasks completed over a ten-week period, enabling effective planning and coordination among team members, ensuring timely and systematic completion of milestones.

Figure 1 Gantt chart of fruit disease detection (see online version for colours)



2 Literature reviews

The literature survey conducted for this research study ‘title’ includes a wide range of current articles, research papers, and scientific publications. The purpose of the literature review is to analyse the current understanding of fruit diseases and its effect on the human life. Through this literature review, we get a deeper knowledge of the relationship between fruit disease and human health, laying the groundwork for the analysis work.

Reddy et al. (2023) in their collaborative research effort, the team introduced the concept for detecting and classifying fruit diseases using colour texture analysis and artificial neural network (ANN) classification. The system uses OpenCV library and K-means clustering for image segmentation. The system was evaluated on various fruits with different diseases, potentially preventing crop for losses and detecting diseases early before it causes more loss. The paper discusses the use of ANNs in fruit disease detection, highlighting its potential in preventing crop losses and improving crop yield and quality. The study outlines the methodology used to train and test the ANN model,

including image data pre-processing, feature selection, and training algorithms. The results show the ANN model outperforms other algorithms in classification accuracy, providing valuable insights into fruit disease detection.

The methodology that they used to build their system are: data acquisition, data pre-processing, and features extraction.

The result of their work is that the ANN algorithm is used for early detection of fruit diseases, preventing potential human life-threatening issues. Datasets are trained and tested using Kaggle, with pre-processing and feature extraction stages. The ANN is then trained, with accuracy achieved over 35 epochs using PyCharm Integrated Development Environment. In this paper it have an solid foundation for the development of a fruit disease detection system using colour and texture analysis, ANN and image processing techniques in which an image processing given out a solution that is proposed for detection of grape, apple and pomegranate fruit disease which cause infection as well as it significantly increasing as an spreading which a speed and accuracy that why they also it also tell us about the details of a fruit diseases.

In conclusion, the paper presents a fruit disease detection system using colour and texture analysis, ANNs, and image processing techniques. It identifies and classifies diseases in grape, apple, and pomegranate fruits, recommending appropriate treatments. The system's accuracy and speed could reduce crop losses and enhance food security (Reddy et al., 2023).

Naziya and Sivaraj (2022) in their collaborative research effort, this paper proposes a solution for detecting and classifying fruit disease by using CNNs and convolutional block attention modules (CBAMs) that help in classifying the data and processing it image analysis.

Fruit cultivation in tropical regions, particularly in Brazil's coastal areas, is crucial for crop diversification and socioeconomic advancement. Papaya, cultivated in over 60 countries, is the world's second-largest producer, with an annual output exceeding 1.5 million tons. Commercialisation of papaya fruit is essential due to its high added value. Early detection and classification of diseases are critical for quality control measures. However, manual quality control remains labour-intensive, time-consuming, and expensive, often unaffordable for farmers in remote regions or small processing facilities. The study aims to overcome limitations in detecting diseases in papaya fruits by creating a new image database with over 23,000 examples of eight types of lesions and healthy fruit samples. The proposed method uses a combination of CBAMs and a YOLOv7 network, demonstrating high accuracy and robustness in identifying injuries. The main contributions include developing a new method for detecting diseases in papaya fruits, providing a new version of the Sisfrutos Papaya image dataset, implementing and testing four additional state-of-the-art detectors, public availability of pre-trained weights for the proposed detector, and providing image annotations in two different formats (TXT and JSON).

The methodology that we used to design our system is: image acquisition, image annotations, the new extended Sofrito's Papaya dataset, and CBAM.

In conclusion, the paper presents that poor-harvest of papaya which caused by the fruit disease significantly challenge for the other sector, necessitates efficiently quality control to multi-wages losses and to ensure that high-quality, healthy fruits for consumers. This study proposes a publicly available image database with multi-class annotations for papaya cultivation, focusing on disease detection. The database contains

23,158 samples divided into nine classes, including diseases and healthy fruit. The proposed detector outperforms state-of-the-art detectors in object detection tasks, achieving an average map of 86.2%. The detector maintains a stable number of parameters and inference times, setting itself as a benchmark for future research. So, the work focuses on improving fruit quality control, industrial automation, precision agriculture, and small rural producers. It proposes techniques for developing embedded systems for fruit processing, enabling autonomous or semi-autonomous disease detection. The system could reduce costs and improve fruit quality. It also suggests that disease detection systems embedded in harvesting robots could improve selective fruit harvesting. The technology could also help rural producers who lack specialised labour to inform their crops about diseases (Naziya and Sivaraj, 2022).

Reddy et al. (2022) in their collaborative research effort, this paper proposes that the fruit disease detection is nothing but analysing the type of disease fruit is suffering from and recommending the pesticide that allow to prevent it. Fruit disease detection is very useful as compared by the manual monitoring by the farmers in agricultural field. The utilisation of CNN calculation clears a simple method for recognising the illness of the products of the soil to separate its disease from healthy fruits. The proposed CNN model is to extract various forms of features by integrating multiple layers.

The key terms that they used in this system are: fruit disease identification, CNNs, and deep learning.

Fruit disease detection is a research field that focuses on identifying diseases automatically, particularly in citrus fruits. These plants are vulnerable to diseases like blackspot, cankers, scabs, greening, and melanoses. Many natural products are rejected due to these diseases, making it crucial to identify them quickly and efficiently. Advances in technology and deep learning have made it easier to identify plant diseases, manage weeds, and reveal important seeds. This study introduces a deep learning model for computerised fruit disease identification, based on CNN-based image grouping. The proposed model classifies fruit disease using computer vision and image processing techniques, suggesting appropriate pesticides for a specific fruit type. It can monitor fruit statues in real-time, enhancing farmers control strategies. The system can be extended to real-world application where it detects the infection or illness of fruits and also providing the reliable disease management solutions.

The methodology that we used to design our system are K-means clustering and ANN.

In conclusion, the CNN model is trained to differentiate between healthy and diseased fruits, identify disease types, and suggest pesticides based on image classification. Data collection, pre-processing, and CNN model application are used to improve disease detection and classification in India's agriculture, contributing to global economic growth. The objective is to boast fruit disease detection system compatibility (Reddy et al., 2022).

Naziya and Sivaraj (2022) in their collaborative research effort, this paper proposes in the field of agriculture fruits are easily get affected by the different-different climatic conditions. For farmers point of view, it is very hard to identify that whether the fruits is disease or not and this also affect the global economy by manual testing of fruits does not give an accurate output as well is take a lot of time to check all the fruits one by one. This method identifies diseases in banana, apple, and orange fruits using colour, shape, and size. It uses a trained system to analyse the input image, extract features like colour, shape, and size, and identify clusters using k-means clustering algorithm. CNN is then

used to determine if the fruit is infected or not. The proposed approach is effective and 95% accurate in identifying diseases in these fruits. India's agriculture is crucial for 58% of the population, but changing climates and diseases are affecting crop yield. As India ranks second in highly populated countries, food consumption is increasing, leading to increased food production. Classifying fruits manually is often inefficient, leading to errors in exporting. Researchers propose an image detection method using CNN to improve classification quality.

In conclusion, fruit disease detection and classification can be tedious due to the difficulty in recognising fruit characteristics. A feature vector model is used to handle this issue. The model undergoes pre-processing, feature generation, and classifier learning stages. The input image is processed using a CNN, extracting features like colour, shape, and size. The output is then mapped to different clusters, indicating whether the fruit is fresh or rotten (Naziya and Sivaraj, 2022).

Dahikarr et al. (2022) in their collaborative research effort, this paper proposes is that fruit crops are crucial for India's economy, nutritional value, and food security. Trees provide shelter, absorb harmful gases, and provide oxygen. Fruits are healthier than junk food, but they can cause diseases. This paper reviews image processing methods for detecting diseases in fruits based on symptoms and highlights research gaps. The goal is to help researchers understand and improve methods for fruit disease detection.

Fruit harvesting is an ancient occupation that relies on farmers for livelihood, employment, energy, and shelter. It contributes to economic growth, health, and low cholesterol, and can help overcome poverty. However, early disease treatment is crucial to prevent fruit extinction and maintain the benefits of the trade. India, the largest fruit promoter, is also known as the fruit crate of the globe. However, due to lack of workforce, poor storage, and wasteful post-harvest administration, India only contributes 1% to the fruit industry. Fruit quality is significantly affected by various diseases. Early detection of fruit contamination can prevent losses and maintain strategic distance from disease spread. Various image processing applications have been developed for the agricultural industry, but disease recognition imaging systems remain challenges. Fruit disease recognition is difficult through manual inspection due to the regular changeability of fruit skin and the presence of different types of diseases. Therefore, it is essential to examine fruit health and disease detection for disease control measures.

The proposed methodology is to developed recommendation system features are image pre-processing, feature extraction, CNN, canny edge detection and the performance analysis of convolution neural network for classification and prediction of pesticides for fruits disease that we depict in the dataset of apple fruit.

In conclusion, this study uses a CNN to classify fruit disease images into blotch, rot, and scab classes. The method is experimentally verified and approved, demonstrating significant support for automatic disease identification and classification (Dahikarr et al., 2022).

Badar and Naaz (2022) in their collaborative research effort, this paper proposes for fruit crops are crucial for India's economy, nutritional value, and human health. Trees provide shelter, absorb harmful gases, and provide oxygen. Fruits are better than junk food, which causes diseases. To prevent early disease infection, this paper reviews image processing methods for detecting diseases in fruits based on symptoms. It highlights research gaps and aims to help other researchers understand fruit disease detection methods. Fruit harvesting, an ancient occupation, relies on farmers' livelihoods,

employment opportunities, energy, and shelter. It can help overcome poverty and contribute to economic growth. Fruits are healthy, low in cholesterol, and provide numerous benefits at a low cost. However, if diseases are not treated early, the trade may lose its benefits and potentially lead to fruit extinction, leaving future generations unaware of its existence.

The key terms of this research paper are image processing, k-means clustering, object tracking, deep learning, and diseases.

Basically, this whole research paper is just a review of all the research paper that are made for the detection of fruit using image processing techniques in which here they take a literature review of 17 research paper through which they create a research gap table in which they analysis the pros and cons of every individual paper and their system design and through which we can predict that the system which we want to design is having this type methodology or algorithm in it. It is very useful to know the current updates and the gap of their research by which we can advanced to a new system design that is easy to handy and give an accurate, precisely, save time and available in affordable prices.

In conclusion, this paper discusses the use of digital techniques like neural networks, object tracking, and K-means clustering to detect infected fruits early on, reducing losses for agriculture, economy, and environment. It provides guidance for researchers interested in this area, aiming to help reduce the burden on farmers (Badar and Naaz, 2022).

Modi et al. (2019) in their collaborative research effort, this paper proposes that to implementation of the algorithm that help us to detect the disease in fruit using image processing more accurately and precisely that why we used MATLAB to perform some operation on image, in order to enhanced image or to extract more useful data. Historically, fruit infections were detected using naked eyes, which was inefficient and costly. MATLAB techniques offer a faster and more accurate method. Symptoms of infections can be seen on various parts of the fruit, including leaves and lesions. The article aims to detect and identify diseases accurately using image segmentation, pre-processing, feature extraction, and identification. The disease can be viral, fungal, bacterial, or insect-related. Fruit features like axis can be extracted from the image, and classification techniques can be used to identify the infection.

India is a developing nation with a significant contribution to the agricultural field. Keen cultivation involves engaging current ranchers with choice instruments and automation advances that coordinate products, learning, and administration for better efficiency, quality, and benefit, where field conditions are controlled and checked using self-working frameworks instead of traditional methods like image processing. Innovations like MRI and X-ray imaging are used to check the quality and defects of fruits, but they are expensive, space-consuming, and require scientific knowledge to analysed results. The established method for detecting and identifying fruit diseases depends on the naked eye perception of specialists, which is costly and difficult to use in developing countries.

Programmed recognition of fruit diseases is crucial to distinguish the indication of diseases as soon as they appear on developing fruits, preventing lost yield, time, creation, and money. Image processing techniques can be used for more accuracy, less time required, and better execution.

Table 1 Literature summary charts

Paper title and author	Introduction	Methodology	Future scope	Result	Gap Analysis	Conclusion
ANN-based fruit disease detection using texture analysis (Reddy et al., 2023)	In their 2023 paper through collaborative research effort, the team introduced the concept for detecting and classifying fruit diseases using colour texture analysis and artificial neural network (ANN) classification.	The methodology we used to build their system are: data acquisition, data pre-processing, features extraction and the system uses OpenCV library and K-means clustering for image segmentation.	This research paper and its system design is developed as according to the need of the current updating where they nearly resolved out the previous system gaps in their system by introducing ANN in it.	The testing accuracy of this system design is 93% where the ANN is used to classifies the data set and it images also here, we use PyCharm to design integrated environmental development in it.	The gap analysis of this system is the improvement of the system's performance and adapt it to different types of fruit diseases and environments is a challenging factor to user.	The paper presents a fruit disease detection system using colour and texture analysis, artificial neural networks, and image processing techniques. It identifies and classifies diseases and also recommending appropriate treatments. The system's accuracy and speed could reduce crop losses and enhance food security.
Yolo-Papaya: a papaya fruit disease detector and classifier using CNNs and convolutional block attention modules (de Moraes et al., 2023)	In the 2023 this paper proposes a solution for detecting and classifying fruit disease by using CNNs and convolutional block attention modules that help in classifying the data and processing it image analysis.	The methodology that we used to design our system are image acquisition, image annotations, the new extended Sofrito's Papaya dataset and convolutional block attention module (CBAM).	The future scope is to developed this system in such a way that user can easily access or used it through their smartphones.	They conduct a lot of research and real-world experiment to maximise it accuracy of detection even in different conditional which maybe can affect the output.	The paper discusses the challenges of poor papaya harvest due to fruit diseases, proposing a publicly available image database for disease detection.	The study aims to improve fruit quality control, industrial automation, precision agriculture, and small rural producers by developing embedded systems for fruit processing.

Table 1 Literature summary charts (continued)

<i>Paper title and author</i>	<i>Introduction</i>	<i>Methodology</i>	<i>Future scope</i>	<i>Result</i>	<i>Gap Analysis</i>	<i>Conclusion</i>
Deep learning-based fruit disease detection	In the 2022 this paper proposes that fruit disease detection is a research field that focuses on identifying diseases automatically, particularly in citrus fruits. This study introduces a deep learning model for computerised fruit disease identification, based on CNN-based image grouping.	The methodology that we used to design our system are K-means clustering and artificial neural network (ANN).	To enhanced the fruit disease detection system to make it more efficient.	The CNN model is trained to differentiate between healthy and diseased fruits, identify disease types, and suggest pesticides based on image classification. Data collection, pre-processing, and CNN model application are used to improve disease detection and classification.	The existing system are only one the basis of image processing where it can sometime give out wrong result.	The objective is to boost fruit disease detection system compatibility.
Fruit disease detection and classification using artificial intelligence	In the 2022 this method identifies diseases in banana, apple, and orange fruits using colour, shape, and size. It uses a trained system to analysed the input image, extract features like colour, shape, and size, and identify clusters using K-means clustering algorithm. convolutional neural network (CNN) is then used to determine if the fruit is infected or not.	The methodology that we used to design our system are convolutional neural network (CNN), and K-means clustering.	To developed it analysis compatibility to resolved the functioning process easily.	The dataset uses a 3D image to calculate length, depth, and width, divides it into small pixels, calculates disease using CNN algorithm, and converts the output into matrix form with 0's and 1's.	The previous system does not have efficiency to produce a pixel segmentation without blurred.	Fruit disease detection and classification are challenging due to fruit characteristics recognition. A feature vector model uses pre-processing, feature generation, and classifier learning to extract features like colour, shape, and size.

Table 1 Literature summary charts (continued)

<i>Paper title and author</i>	<i>Introduction</i>	<i>Methodology</i>	<i>Future scope</i>	<i>Result</i>	<i>Gap Analysis</i>	<i>Conclusion</i>
Fruit disease detection and pesticides recommendation system	In the 2022 this paper discusses the importance of fruit crops in India's economy, nutritional value, and food security, focusing on image processing methods for detecting diseases and identifying research gaps.	The methodology that we used to design our recommendation system are, feature extraction, convolutional neural network, canny edge detection and the performance analysis of convolution neural network for classification.	The future scope of there system is to work on their own experiments and signifies a support automation solution for identification and classification in it.	The study analyses the performance of a convolutional neural network for pesticide classification and prediction on apple datasets, discussing its execution and proficiency.	The existing system directly give out the result even the image of the analysis is blurred an So that is why they introduced a lot of methodologies in their system to make it more accurate.	The study employs a convolutional neural network to automatically classify fruit disease images into blotch, rot, and scab categories, demonstrating significant support for automatic disease identification and classification.
Detection of fruit diseases using image processing techniques: a review	In the 2022 this paper discuss there are no methodologies that we used in it; this is just a review of past-designed systems that detects the techniques and methods that we used to create an updated version. That's why our research team analysed the past-designed systems and their pros and cons. fruit disease.	There are no methodologies that we used in it; this is just a review of past-designed systems that detect fruit disease.	There is no future scope in this because this research paper is a review of all the image processing techniques system.	This research paper reviews 17 and the goal is to predict future systems with similar methodologies and algorithms, enabling the development of more accurate, precise, time-saving, and affordable systems through the help of research gap table.	There is no gap analysis in these.	This paper explores the use of digital techniques like neural networks, object tracking, and K-means clustering to detect infected fruits early, reducing losses for agriculture, economy, and environment.

Table 1 Literature summary charts (continued)

<i>Paper title and author</i>	<i>Introduction</i>	<i>Methodology</i>	<i>Future scope</i>	<i>Result</i>	<i>Gap Analysis</i>	<i>Conclusion</i>
Implementation of algorithm to detect the diseases in fruit using image processing technique	In the 2022 this paper proposes an algorithm for accurately detecting fruit diseases using image processing using MATLAB techniques, replacing the inefficient and costly method of detecting fruit infections using naked eyes.	The methodology that we used to design our system are image acquisition, image pre-processing, image segmentation, feature extraction and disease detection.	In the future, they will work on the SYD approach to analysed the disease in fruits in the prior stage.	The paper discusses the study of diseases in fruits using a software approach, which saves time compared to manual methods. It uses a de-noising process to remove distortions in images, and uses image processing techniques for early detection.	To make the data more visible they further used MATLAB so they can also replace insufficient techniques in it.	The paper presents a software-based method for studying fruit diseases, utilising de-noising to remove distortion and early detection through pre-processing, extraction, and single-valued analysis.
Fruit disease detection using color analysis and ANN with e-nose	In their 2017 paper 'Fruit disease detection using color analysis and ANN with e-nose', Neha Mundokrand a research team introduced fruit detection using colour analysis and ANN (artificial neural network) with e-nose.	In this research paper we use both algorithm and methodologies to design a system that detect fruit disease.	The research paper sets are made as per the deficient accuracy of data where the image of data where the image processing cannot able to find out the output and through the analysis it gives whether the fruit is infected or not.	They study and compared existing systems using image processing techniques to finding that whether we are able to find the disease of fruit up to 93% but the result is only the basis of their colour and textured that's why we modified our system by introducing e-nose in it.	A gap analysis of the research paper 'Fruit disease detection using color analysis and ANN with e-nose', highlights several areas for further investigation.	The team's pioneering work has laid the preparation for e-nose, providing valuable efficiency while image processing as well as sense the fruit odour/aroma which used to detect whether the fruit is infected of not.

Table 1 Literature summary charts (continued)

<i>Paper title and author</i>	<i>Introduction</i>	<i>Methodology</i>	<i>Future scope</i>	<i>Result</i>	<i>Gap Analysis</i>	<i>Conclusion</i>
Fruit disease detection and classification	In the 2017 paper for detecting and classifying fruit disease using an image processing approach. The method uses K-means clustering for segmentation, extraction features, and uses a support vector machine to detect the disease accurately and precisely.	The methodology we used to build their system are K-means clustering and support vector machine (SVM).	There is no predefined future scope because according to researcher the main objective is them to enhance the value of fruit disease detection.	The fruit disease classification problem requires precise image segmentation, using K-means-based segmentation. Features are extracted, and training and classification are performed using a SVM classifier.	In the existing system approach K-means based image segmentation is preferred to detect the region of interest which is the infected part only.	The leading objective of their paper is to enhance the value of fruit disease detection.

In conclusion, the paper discusses the study of diseases in fruits using a software approach that saves time compared to manual methods. The de-noising process removes distortion in images, primarily affecting bacterial blight. The system uses blurred images for early detection using techniques like pre-processing, extraction, and single-valued analysis. Future work will focus on the SVD approach for cost-effective analysis of fruit diseases in the prior stage (Modi et al., 2019).

Mundokar et al. (2017) in their collaborative research effort, the team introduced the concept of using e-nose, an innovative approach that enable to overcome the deterioration of image processing analysis. Their work primarily focuses on addressing the challenge to detect the disease and provides preventive measure of in this decentralised setting.

Key contributions of the research include:

- 1 *System averaging:* The team proposed a technique known as e-nose which basically work on the sense of odour/aroma. This approach involves in our system helps the model to give an accurate output, reducing the loss of fruits and save time.
- 2 *Local updates:* To enhance scalability, we allow multiple inputs in while processing the data to the central server. This strategy effectively reduces consume of pixels in an image.
- 3 *Model compression:* The research explores various techniques that used in pixels for the intensity, thereby improving the efficiency of thresholding methodologies in it. The algorithm that we used in it are canny edge detection algorithm, noise reduction, and find intensity gradient of the image, non-maximum suppression, and hysteresis thresholding. And the methodologies are: image acquisition, image processing, grey scale image, edge detection, morphological operations, thresholding, segmentation, extracting AOI, and e-nose.
- 4 *Differentially new technologies introduced:* The paper highlights the importance of e-nose which overcome the deterioration of image processing in the refereed old system and due to which we can able to produce large amount of good product in a required time.

In conclusion, based on the information available, this research paper they introduced a new technology in their system e-nose which helps in for providing better output even if sometimes image processing result is not accurate. The e-nose sense the odour/aroma of the fruit to detect whether it is infected or not. It also gives the preventative means for infected fruit and indirectly it turns out a good results (as per Table 1) production of fruits. The major objective is this paper is to detect the disease and provide preventive measure (Mundokar et al., 2017).

Gaikwad et al. (2017) in their collaborative research effort, this paper proposes a solution for detecting and classifying fruit disease using an image processing approach. The method uses K-means clustering for segmentation, extraction features, and uses a SVM our experimental result expressed a way to propose a solution that can significantly support accurate detection and automatic classification of the fruit diseases which help us to detect the disease accurately and precisely.

Fruit diseases can cause significant losses in the yield and its quality during harvesting. Automatic detection is crucial to identify symptoms early. Common diseases include apple scab, apple rot, and apple blotch. Machine vision can automate visual inspection, but detection remains problematic due to skin colour variability, defect types,

and stem/calyx presence. Monitoring health and detecting diseases within a fruit is critical. Proper management actions, such as pesticides, fungicides, and chemical applications, can promote disease control and improve quality. This work proposes a solution for detecting and classifying fruit diseases using spectroscopic and imaging technology. As commercialisation increases, agricultural farms aim to reduce manpower without affecting productivity. Fruit detection systems are primarily used in robotic harvesting but can be customised for other applications. Precision agriculture helps farmers provide economic information and control technology, aiming for agricultural input systemisation, profit hike, and environmental damage reduction. The technique helps farmers identify infected or non-infected fruits.

Existing system is classifying three normal apple fruit infections: apple scab, apple rot, and apple blotch, using only image processing and random forest classifier to detect a disease in classification.

Proposed system is that the classification of fruit disease problem requires a precise image segmentation, using K-means-based segmentation and features are extracted, and training the classification by using a SVM classifiers.

- 1 It would promote Indian Farmers to use smart farming methods so it can save time as well as reduces the loss of fruit that caused due to diseases.
- 2 The leading objective of their paper is to enhance the value of fruit disease detection.

In conclusion, the paper presents a fruit disease detection and classification this paper proposes an image processing-based solution for detecting and classifying fruit diseases using K-means clustering, extracting features, and training on SVM. The approach promotes smart farming, saving time and reducing fruit loss, aiming to enhance the value of fruit disease detection (Gaikwad et al., 2017).

3 Methodology

3.1 Use case diagram

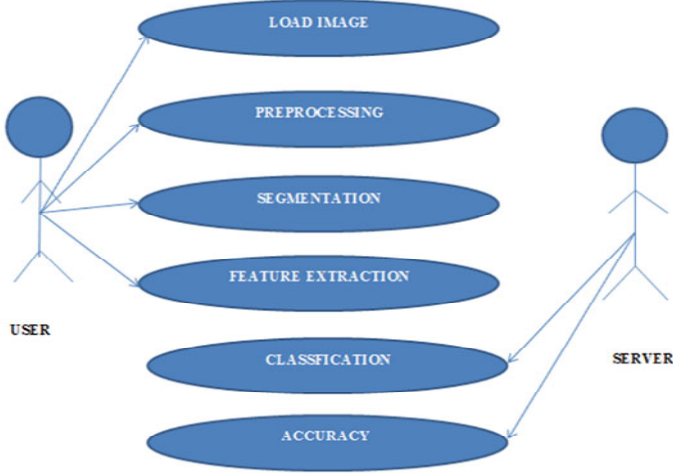
The use case flow diagram outlines the sequential interactions within the system involving two primary actors: user and server. The diagram captures the key functionalities and interactions that facilitate a seamless flow of actions in the system (as per Figure 6).

- 1 *User:*
 - *Upload image:* The user can upload an image of fruit for disease detection.
 - *Request analysis:* The user can request the system to analyse the uploading for disease detection.
- 2 *Server:*
 - *Pre-process image:* The server pre-processes the upload image, extracting relevant features like colour and texture.
 - *Apply colour analysis:* The system analysis the texture features of the fruit image.

- *Use ANN for detection:* The system uses an ANN to perform disease detection based on the extracted features.
- *Generate report:* The server generates a report indicating the detected disease and its severity.

The flow of interaction between the ‘user’ and ‘server’ is represented by arrows, with the ‘user’ uploading an image, requesting analysis, and the ‘server’ processing, applying, and generating reports.

Figure 6 Use case diagram (see online version for colours)



3.2 ER diagram

In an entity-relationship diagram that represents the system, the entities ‘user’, ‘image’, ‘analysis request’, and ‘report’ are likely key components of the database schema. Each entity is associated with specific attributes that define the characteristics or properties of that entity (as per Figure7).

- Entities (user, image, analysis request, and report) are represented as classes.
- External entities (user and fruit disease detection system) are represented as actors.
- Data stores (UploadedImage and AnalysisResult) are represented as data classes.
- Processes (ImageUpload, ImageAnalysis, and ReportGeneration) are represented as processes.

This is a simplified representation and may need further details based on your specific system requirements. You can customise and expand this example according to your needs.

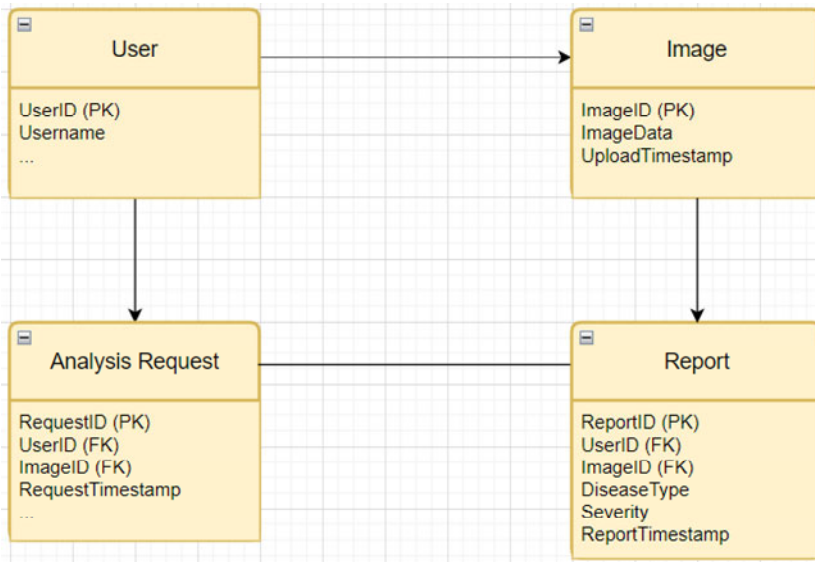
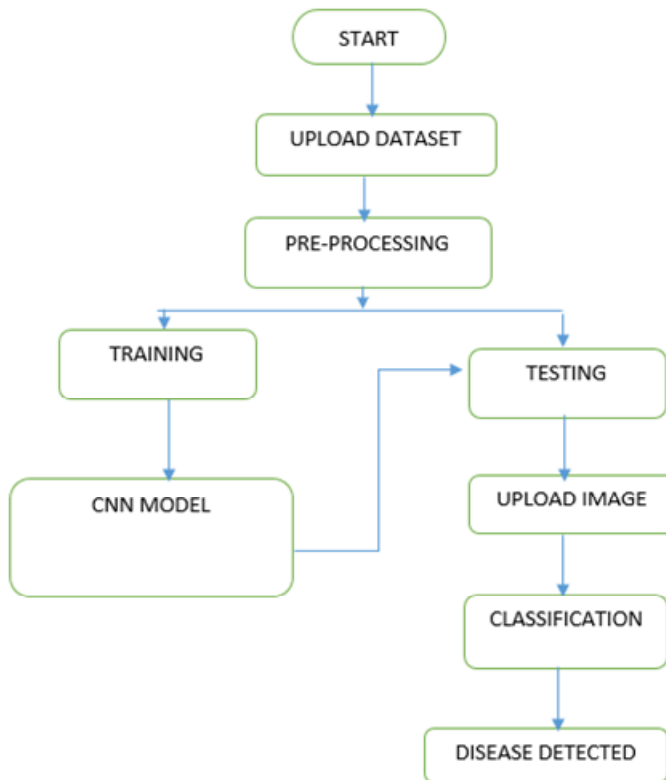
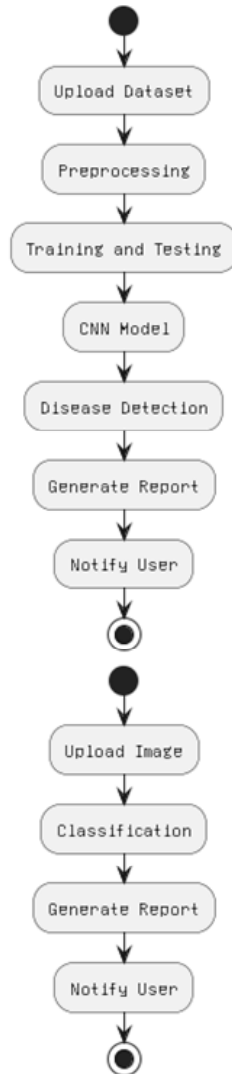
Figure 7 Entity relation diagram (see online version for colours)**Figure 8** Data flow diagram (see online version for colours)

Figure 9 Flowchart



3.3 Data flow diagram

The data flow diagram depicts data transit and transformation inside the pre-processing of the fruit disease detection system, which integrates by uploading images that go for training on the CNN model. Despite testing, it uploads images and the data flows between the user interface and the backend components of the program, allowing for texture analysis, colour analysis, and classification of disease. The data flow diagram vividly displays the various data channels, emphasising the system's safe, transparent, and simplified administration.

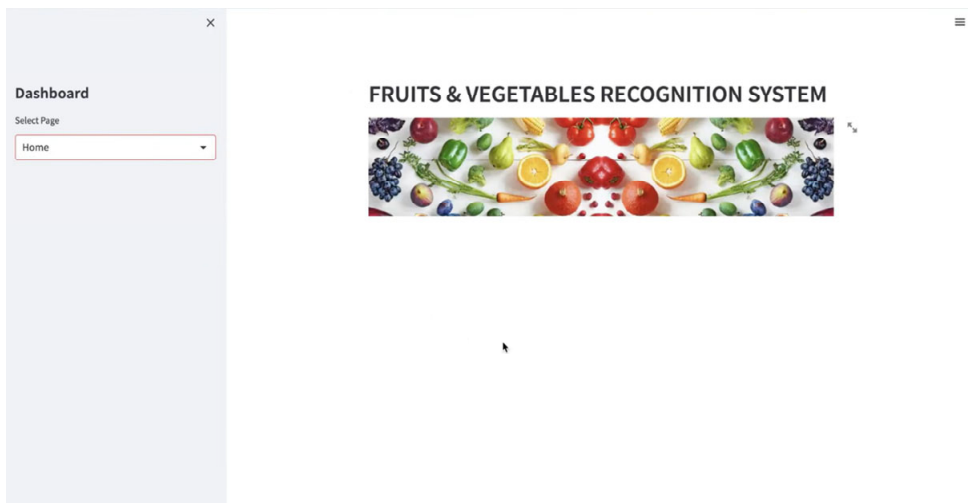
3.4 Flowchart

The flowchart starts with the ‘start’ point and covers various processes like dataset upload, pre-processing, CNN model training, disease detection, report generation, and user notification. It also has a branch for uploading single images for classification. Customise the flowchart based on specific steps and decision points.

4 Result and discussion

The landing page of our website presents a clean and user-friendly interface, which invite user and show what it is used for and we make it so simple even a kid can check whether the pictured is a fruit or vegetable and it also used for reorganisations it. We provide a powerful solution for early and accurate detection of diseases in fruit crops (as per Figure 10).

Figure 10 Homepage (see online version for colours)



This page show about the project dataset which a user can check the configuration at a time. The project’s models are fine-tuned for accuracy, adaptability, and ethical data handling. It is a community of farmers, researcher, and agricultural enthusiasts working towards a sustainable future for agriculture (as per Figure 11).

Here we can predict the browsing image is a fruits/vegetable and here we can input maximum of 200 MB file which we can browse through our file and upload it and also we can see the image which we uploaded on it and prediction button here click and then show the name of the fruits/vegetables (as per Figure 12).

In this figure as you can see how we can easily browse our image to the website (as per Figure 13).

Figure 11 About project

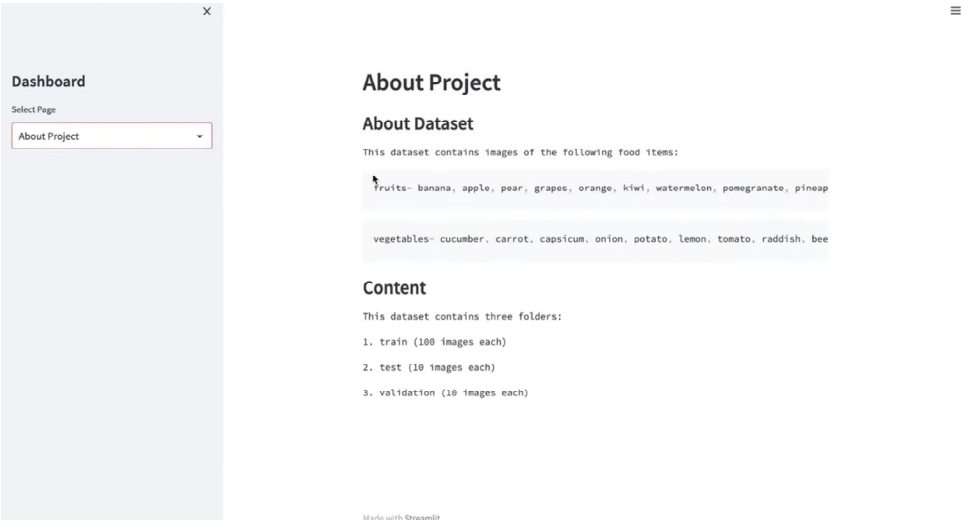
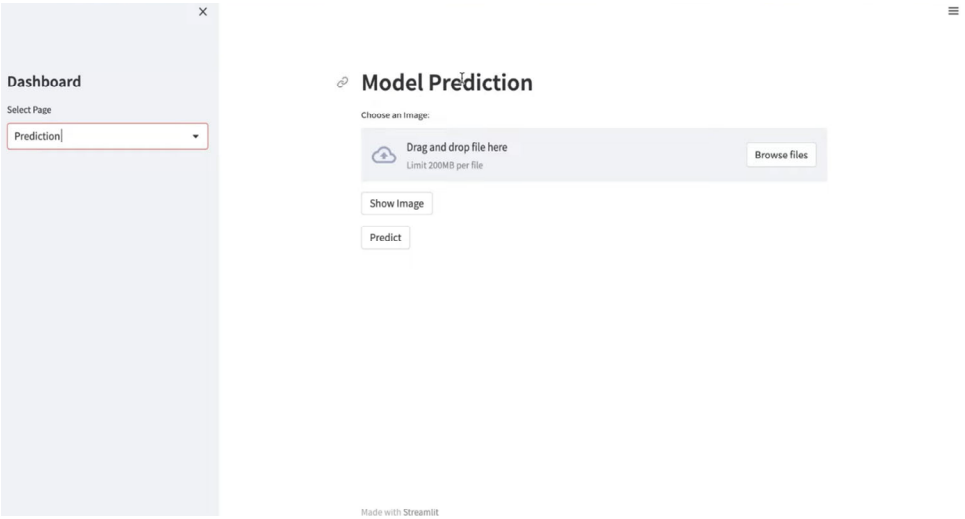
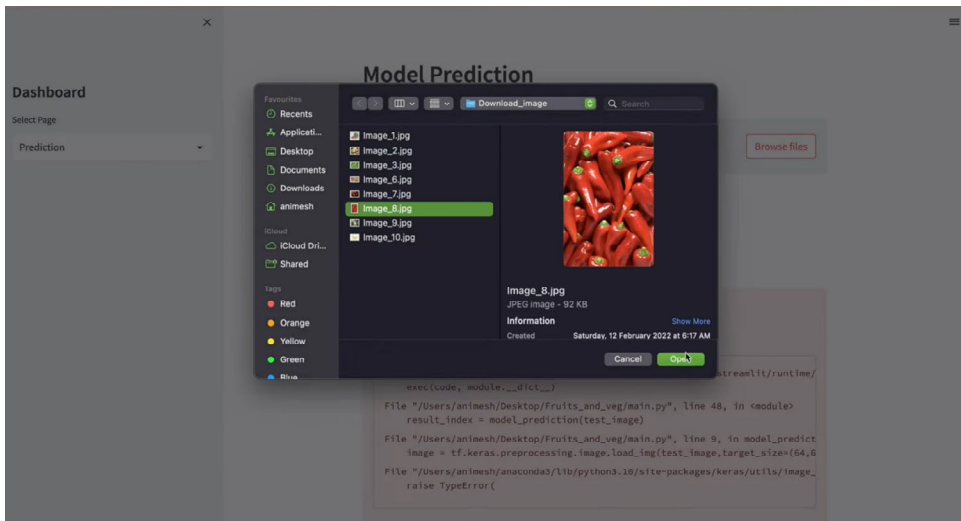
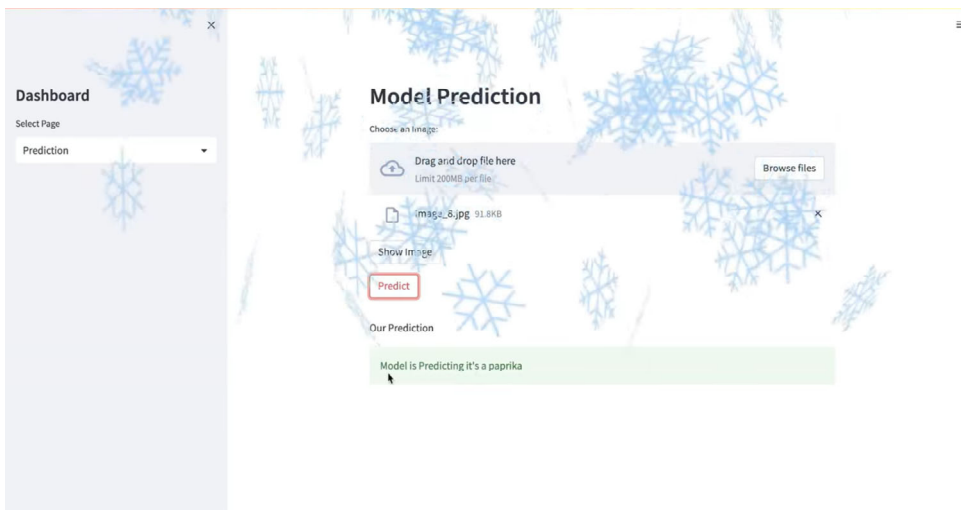


Figure 12 Model prediction



In this figure as you can see it show the result/name of the given fruit and vegetable which that image from our browsing file contains (as per Figure 14).

In Figure 15, we can see that it shows the name of fruits and vegetables, and through its texture and fruit image classifications in ANN, it's shown whether the given image of an object is defective or not. Our project is designed to not only identify various fruits and vegetables through their distinctive textures but also to revolutionise the way we detect defects or diseases in these crops using advanced ANNs (as per Figure 15).

Figure 13 Browsing image (see online version for colours)**Figure 14** Prediction (see online version for colours)

Visualising a fruit disease detection system's training and validation graph involves plotting metrics over time to assess performance and generalisation. Common components include epochs on the X-axis, metrics on the Y-axis, training and validation loss, training and validation accuracy, training and validation loss curves, early stopping points, and learning rate schedules. The goal is to see a decreasing trend in both curves, indicating effective learning, but be cautious of overfitting. Early stopping points should be marked to prevent degradation in performance on the validation set (as per Figure 16).

Figure 15 Texture and colour analysis (see online version for colours)

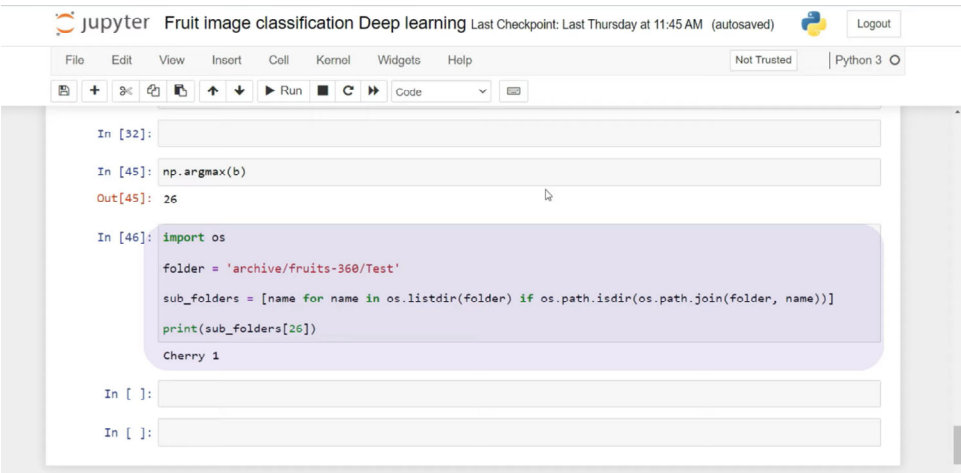
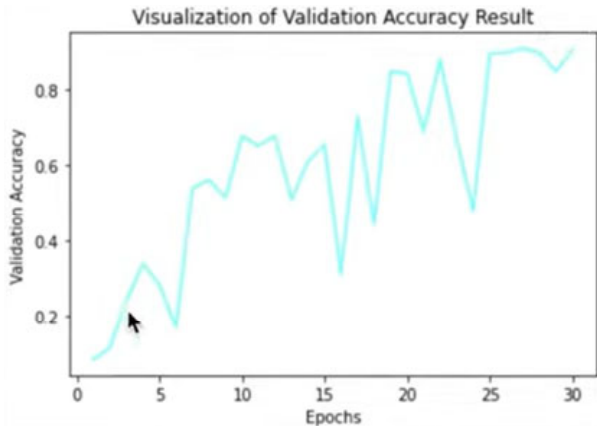


Figure 16 Visualise train result (see online version for colours)



Figure 17 Visualise validation result (see online version for colours)



To visualise a fruit disease detection system's validation accuracy graph, use a line plot with a horizontal axis representing training epochs and a vertical axis representing validation accuracy. Include markers at each epoch for better visibility. Provide a title for the graph, label the x-axis and y-axis, and include a grid and legends for easy reading and comparison of models or configurations (as per Figure 17).

The KNN accuracy graph for the fruit disease detection system uses colour, texture, and ANNs to display the system's performance across different K values. The graph demonstrates how the system's accuracy changes as K values vary, allowing for trend analysis and optimal K selection. The graph helps in decision-making by highlighting the sensitivity of the system to the choice of K, allowing for better performance without overfitting. It can also be used for experimentation and further analysis, such as assessing the system's stability and robustness (as per Figure 18).

Figure 18 KNN accuracy graph (see online version for colours)

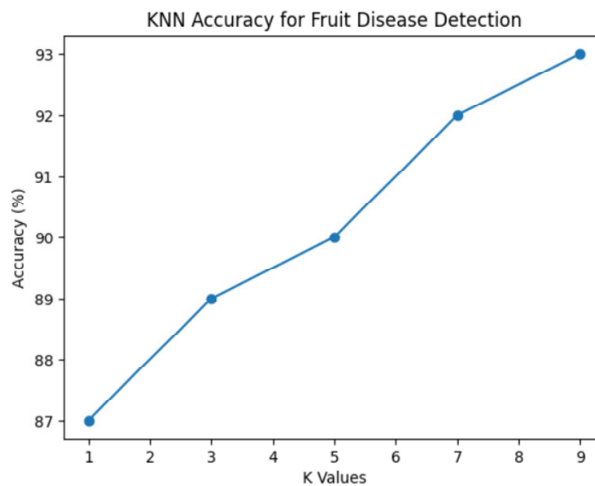


Figure 19 Comparison bar chart for different algorithms (see online version for colours)

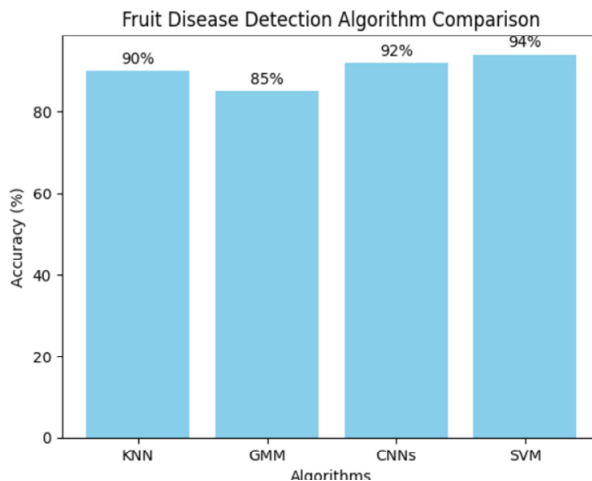


Table 2 Comparative analysis of presented approach with current state of art

<i>Paper</i>	<i>Advantages</i>	<i>Disadvantages</i>	<i>Gap</i>	<i>Finding</i>	<i>Accuracy</i>
ANN-based fruit disease detection using texture analysis	The proposed system uses colour and texture analysis and an artificial neural network to detect fruit diseases early, preventing disease spread and minimising crop losses. It can detect diseases in various fruits like grapes, apples, and pomegranates, and uses multiple features like colour, morphology, texture, and structure. The system also uses image processing techniques like K-means clustering for effective analysis.	The system's effectiveness depends on image quality, with low resolution or noise impacting disease detection accuracy. It's limited to specific fruits like grapes, apples, and pomegranates, and its algorithm complexity, involving colour texture analysis, K-means clustering, and artificial neural networks, may require additional training.	The paper mentions a Kaggle dataset but lacks specific details about its size, diversity, and sources. It also lacks a comparative evaluation, suggesting a need for more robustness and comparisons.	The proposed system achieves a 93% accuracy rate, demonstrating the potential effectiveness of combining colour texture analysis and artificial neural networks for fruit disease detection.	The proposed system, with a 93% accuracy rate, effectively classifies and detects fruit diseases, making it a promising tool for practical implementation in the agriculture industry.
Yolo-Papaya: a papaya fruit disease detector and classifier using CNNs and convolutional block attention modules	The authors developed a comprehensive dataset of 23,158 papaya fruit diseases, focusing on diversity. They introduced a novel detection method combining convolutional block attention modules (CBAM) and the YOLOv7 framework, enhancing the model's focus on relevant features. The Yolo-Papaya detector achieved an overall mean average precision of 86.2%, accurately identifying various diseases and distinguishing healthy fruits.	The study highlights the challenge of comparing different techniques due to self-built datasets, but does not fully address this issue. The generalisability of the proposed model to real-world scenarios may be affected. Additionally, the study does not fully explore the computational demands of the Yolo-Papaya detector, which could be crucial for researchers with limited resources.	The paper highlights the lack of standardisation in fruit disease image datasets, stating that there is a need for a broader initiative or guideline to facilitate fair comparisons and research advancements.	The Yolo-Papaya detector, a state-of-the-art method for papaya fruit disease detection, outperforms existing methods on large datasets, indicating potential practical utility in real-world applications.	The Yolo-Papaya detector achieved an impressive 86.2% overall mAP, demonstrating high accuracy in identifying and classifying diseases affecting papaya fruits, with exceptional performance in 'healthy fruits' and 'phytophthora blight'.

Table 2 Comparative analysis of presented approach with current state of art (continued)

<i>Paper</i>	<i>Advantages</i>	<i>Disadvantages</i>	<i>Gap</i>	<i>Finding</i>	<i>Accuracy</i>
Deep learning-based fruit disease detection	The proposed model automates disease identification for fruit, reducing farmers' reliance on manual monitoring. It includes a pesticide recommendation system for comprehensive plant health solutions. The model's versatility allows it to be applied to various fruits and integrates deep learning techniques for real-time monitoring, enabling timely interventions.	The effectiveness of a deep learning model heavily depends on the quality and diversity of the training dataset, which can be limited or biased. Computational resources, particularly for CNNs, can be challenging in resource-constrained environments. Additionally, CNNs are often considered 'black-box' models, making interpretation challenging for users seeking transparency.	The paper lacks discussion on model generalisation and performance in diverse environments, which is crucial for practical deployment. Additionally, there is a gap in real-world validation of the model's performance in agricultural settings, necessitating field trials and larger scale validation.	The model effectively identifies and recommends fruit diseases using K-means clustering, artificial neural networks (ANN), and convolutional neural networks, providing valuable recommendations for farmers.	The paper lacks specific details on the proposed model's accuracy metrics or validation results, making it difficult to assess its reliability and effectiveness in practical applications.
Fruit disease detection and classification using artificial intelligence	The system automates disease detection in fruits using image analysis, reducing manual testing and improving agricultural productivity. It supports various fruits like banana, apple, and orange, and integrates convolutional neural network (CNN), K-means clustering, and image processing techniques. The system achieves a high accuracy of 95%, demonstrating its effectiveness in identifying and classifying diseases in fruits.	The system's disease detection accuracy relies on high-quality input images, which can lead to misclassifications. The system's accuracy is limited to the trained dataset, which may not represent all fruit disease variations. The use of CNN and K-means clustering adds complexity. Environmental factors can also impact the system's performance.	The system's usability may be hindered by lack of familiarity with image processing technologies, but a user-friendly interface and educational resources could improve accessibility. Real-time monitoring could enhance its practical utility for timely disease management.	The CNN and K-means clustering method effectively identifies and categorises fruits based on diseases, emphasising the importance of combining multiple techniques for comprehensive results.	The proposed approach achieves 95% accuracy in identifying diseases in banana, apple, and orange fruits, indicating its reliability in practical scenarios. It presents a promising solution for automated fruit disease detection, but improvements in image quality and real-time monitoring could enhance its practicality.

Table 2
Comparative analysis of presented approach with current state of art (continued)

<i>Paper</i>	<i>Advantages</i>	<i>Disadvantages</i>	<i>Gap</i>	<i>Finding</i>	<i>Accuracy</i>
Fruit disease detection using color, texture and ANN (our presented approach)	The system uses colour and texture features for fruit disease detection, providing a comprehensive analysis. It uses artificial neural networks (ANN) for advanced pattern recognition, recognising intricate patterns associated with fruit diseases. This combination improves accuracy, as ANN excels at learning from data and making predictions. The system is applicable to various fruit types, allowing farmers to use the same system for different crops. Additionally, colour and texture features are robust to variations in environmental conditions, making them suitable for real-world scenarios. We used a personal date set in our system.	Image quality affects disease detection accuracy, while sufficient training data is crucial for accurate predictions. Insufficient variety or lack of representative data can hinder ANN performance. Computational resources can also pose challenges, especially in resource-constrained environments.	ANN's pattern recognition capabilities are impressive, but lack transparency in decision-making. Addressing this gap could boost user trust and make the system more suitable for real-time implementation, despite potential challenges.	The study indicates that combining colour and texture features effectively aids in detecting fruit diseases, underscoring the significance of feature fusion in enhancing system performance.	The fruit disease detection system achieved 90% accuracy on a testing dataset, demonstrating its efficacy in identifying and classifying diseases based on colour and texture features.

There is not a single algorithm that is universally used for fruit disease detection relies on various algorithms and techniques, including CNNs, SVMs, random forest, K-nearest neighbours (KNNs), deep learning architectures (VGG, ResNet, and inception), decision trees, Gaussian mixture models (GMMs), and transfer learning. These algorithms are used for image-based tasks, classification, regression, clustering, and classification tasks. The choice of algorithm depends on the specific requirements, dataset characteristics, and preferences of researchers or practitioners. Factors such as interpretability, computational resources, and the trade-off between accuracy and training time also play a role in the selection process (as per Figure 19).

5 Novelties

- *Self-supervised learning*: Where the model learns from the inherent structure of the data without relying on external labels. This approach could be beneficial when the labelled datasets are limited.
- *Privacy and security*: Measures into the design and deployment of fruit disease detection systems, developers can build trust among the users and stakeholders, ensuring the responsible and secure use of agricultural data.
- *Explainable AI with interactive features*: It incorporate the interactive features like visualisations. Heatmaps, and interfaces to improve exploitability and provide users with insights into the model's decision-making process.
- *Real-time feedback*: Where the model continuously learns from newly captured images and updates its knowledge base. This is a dynamic learning approach that ensures the model remains adaptive to changing environmental and disease conditions.

6 Recommendations

To improve the fruit disease detection system, several recommendations are suggested. This includes data augmentation and diversity, balancing the class distribution and model evolution. Our system provides a user-friendly interface which is make it more comfortable for user to use it, and the previous data history can also be deleted or saved. It's user choice, and to use it there is no limitation. This system also contains the theory about the different diseases that can be detected and also show the way to resolved them.

7 Future research direction and limitation

7.1 Limitations

Fruit disease detection using colour texture and ANNs faces several limitations and challenges. Data limitations, such as insufficient labelled data, class imbalances, and generalisation across different environments, can hinder the performance of ANN models. Interpretability is also a challenge due to the inherent complexity of neural

networks. Computational resources are also a challenge, as training and deploying complex ANN models can be computationally intensive. Overfitting and hyperparameter tuning are also issues, especially when dealing with small datasets. Image quality, the dynamic nature of diseases, and limited explain ability can also impact the model's performance. Ethical considerations, such as respecting privacy rights, are also important. Addressing these limitations is crucial for responsible fruit disease detection systems, and ongoing research and advancements in technology could lead to more modification and widely applicable solutions.

7.2 *Future directions*

Fruit disease detection systems using colour, texture, and ANNs are set to evolve in the future. Key areas of research include advanced neural network architectures, explainable AI, edge computing, IoT integration, collaboration with agricultural experts, multi-sensor fusion, mobile applications, crowdsourced data, citizen science, continuous dataset expansion, sustainability, and ethical considerations. Increasing its accuracy and reducing its mistakes that occur in the imputation of the same type of dataset, which show different-different output. And make it more AI integrated, which makes it easy to use.

8 **Conclusions**

In conclusions, the integration of colour and texture analysis with ANNs for fruit disease detection is a promising approach. This method uses ANN's ability to learn intricate patterns from complex data and the nuanced information provided by colour and texture features. It offers comprehensive feature representation, adaptability to varied conditions, effective learning, real-time application potential, and contributes to precision agriculture by enabling targeted treatments. However, challenges such as substantial labelled data, potential overfitting, and hyperparameter tuning need to be addressed. Future research and collaboration with domain experts can refine the methodology and adapt it to specific crops and diseases. Technological advancements in neural network architectures and training strategies could further enhance fruit disease detection systems. In the fusion of colour texture analysis with ANN-based models represents a significant step forward in the realm of fruit diseases detection.

The integration of colour and texture analysis with ANNs in fruit disease detection offers a versatile and effective method for identifying and diagnosing plant diseases. The combination of colour and texture features improves the model's ability to distinguish between healthy and diseased fruits. ANN's robustness allows for effective learning and adaptation to diverse imaging conditions, making them suitable for real-world applications. They can efficiently learn complex patterns and relationships within the data, facilitating effective disease detection. ANNs are scalable and computationally efficient, making them suitable for deployment in resource-constrained environments. Future research could explore the integration of advanced neural network architectures and collaborations with agricultural experts to modify the model's accuracy and applicability to specific crops and diseases.

Ethical committee and funding

The introduction lays the groundwork for understanding the critical function of fruit disease detection system which helps to minimum the losses of the agricultural yielding of crop. The research objectives for fruit disease detection using colour, texture, and ANNs are clearly stated. Ethical considerations are discussed, including the process of submitting the proposal to an ethical committee and informed consent. Funding is crucial for agricultural research and technology development, and potential sources are identified. The grant proposal is provided, outlining the project's objectives, methodology, and expected outcomes.

References

- Badar, F. and Naaz, A. (2022) 'Detection of fruit diseases using image processing techniques: a review', *SSRG International Journal of Electronics and Communication Engineering*, Vol. 9, No. 4, ISSN: 2348-8549, <https://doi.org/10.14445/23488549/IJECE-V9I4P102>.
- Dahikarr, A.P., Bansod, S., Amate, K., Hudekar, P.P., Langde, S. and Fatinge, P. (2022) 'Fruit disease detection and pesticides recommendation system', *International Journal of Advances in Engineering and Management*, Vol. 4, No. 12, ISSN: 2395-5252, https://ijaem.net/issue_dcp/Fruit%20Disease%20Detection%20and%20Pesticides%20Recommendation%20System%20.pdf.
- de Moraes, J.L., de Oliveira Neto, J., Badue, C., Oliveira-Santos, T. and de Souza, A.F. (2023) 'Yolo-Papaya: a papaya fruit disease detector and classifier using CNNs and convolutional block attention modules', *Electronics*, Vol. 12, <https://doi.org/10.3390/electronics12102202>.
- Gaikwad, S.A., Deore, K.S., Waykar, M.K., Dudhane, P.R. and Sorate, G. (2017) 'Fruit disease detection', *International Research Journal of Engineering and Technology*, Vol. 4, No. 12, ISSN: 2395-0056, <https://www.irjet.net/archives/V4/i12/IRJET-V4I12213.pdf>.
- Mehmood, A., Ahmad, M. and Ilyas, Q.M. (2023) 'On precision agriculture: enhanced automated fruit disease identification and classification using a new ensemble classification method', *MDPI*, Vol. 13, No. 2, p.500, <https://www.mdpi.com/2077-0472/13/2/500>, <https://doi.org/10.3390/agriculture13020500>.
- Modi, H., Patel, M. and Patel, H. (2019) 'Implementation of algorithm to detect the diseases in fruit using image processing technique', *International Journal of Applied Engineering Research*, Vol. 14, No. 9, ISSN: 2093-2106, https://www.ripublication.com/ijaer19/ijaerv14n9_04.pdf.
- Mundkar, N., Kale, P., Bhalgat, M., Koske, S. and Thorat, P. (2017) 'Fruit disease detection using color analysis and ANN with e-nose', *Imperial Journal of Interdisciplinary Research*, Vol. 3, No. 5, ISSN: 2454-1362, URL:https://www.academia.edu/36326904/Fruit_Disease_Detection_Using_Color_Analysis_and_ANN_with_E_No.
- Naziya, S. and Sivaraj, C. (2022) 'Fruit disease detection and classification using artificial intelligence', *International Research Journal of Engineering and Technology*, Vol. 9, No. 8, ISSN: 2395-0056, <https://www.irjet.net/archives/V9/i8/IRJET-V9I8329.pdf>.
- Reddy, B.S.V., Kumar, V., Reddy, M.V., Dudhane, P.R. and Sorate, G. (2022) 'Fruit disease detection', *International Research Journal of Modernization in Engineering and Technology and Science*, Vol. 4, No. 1, ISSN: 2582-5208, https://www.irjmets.com/uploadedfiles/paper/issue_1_january_2022/18556/final/fin_irjmets1643102367.pdf.
- Reddy, G.N., Gowthami, L., Eshwar, P., Reddy, P.S. and Reddy, K.M.S. (2023) 'ANN-based fruit disease detection using texture analysis', *Journal of Emerging Technologies and Innovative Research*, Vol. 10, No. 4, ISSN: 2349-5162, <https://www.jetir.org/papers/JETIR2304425.pdf>.

Appendix

Key terms and definitions

- *ANNs*: consist of input, hidden, and output layers with connected neurons (nodes) to simulate the human brain. The existing nodes process and transmit input signals to the next nodes.
- *Training data*: is the data you use to train an algorithm or machine learning model to predict the outcome you design your model to predict.
- *Learning algorithms*: consists of a loss function and an optimisation technique.
- *Classification metric*: the key features are: accuracy, recall, precision, and F1-score.
- *Precision agriculture*: is an algorithm returns more relevant results than irrelevant ones.
- *Python*: is commonly used for developing websites and software, task automation, data analysis, and data visualisation.
- *OpenCV*: is a great tool for image processing and performing computer vision tasks.
- *TensorFlow*: can be used to develop model for various tasks, including natural language processing, image recognition, handwriting recognition, and different computational-based simulations such as partial differential equations.
- *PyTorch*: is a fully featured framework for building deep learning models, which is a type of machine learning that's commonly used in applications like image recognition and language processing.
- *Data augmentation*: is a technique of artificially increasing the training set by creating modified copies of dataset using existing data.
- *Explainable AI (XAI)*: is a set of processes and methods that allows human users to comprehend and trust the result and output created by machine learning algorithms.
- *HyperText Markup Language (HTML)*: is the code that is used to structure a web page and its content.
- *CSS is the acronym of 'Cascading Style Sheets'*: CSS is a computer language for laying out and structure web pages (HTML or XML).
- *JavaScript*: is a scripting language that enables you to create dynamically updating content, control multimedia, animate images, and pretty much everything else.
- *Streamlit*: is a free and open-source framework to rapidly build and share beautiful machine learning and data science web apps.