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3.

DIGITAL TWIN IN AGRICULTURE SECTOR

DETECTION OF DISEASE USING DEEP LEARNING

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CONTENTS

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3.1 - INTRO: BACKGROUND & DRIVING FORCES

- Agricultural plants are often affected by diseases and pests, leading to decreased production.
- Plant diseases are mostly caused by bacteria, fungi, and viruses, which can cause a 10% loss in world production.
- Traditional methods of plant disease detection are susceptible to errors, so new technologies are being developed.
- Plant image sensors, including multi-spectral, optical, gravimetric, conductivity, hyperspectral, and thermography sensors, show promise in monitoring plant diseases.
- Symptoms of plant diseases include leaf curling, morphological changes, chlorosis, premature abscission of plant, and change in leaf angle, stunting, or wilting.
- Disease detection is essential in the agricultural field to prevent economic damage caused by reduced yields and the high cost of pesticides.
- Image processing and machine learning algorithms can be utilized with imaging sensors to analyze and detect plant diseases.

3.2 – LITERATURE REVIEW

REMOTELY DISEASE SENSING

- Remotely sensed and monitored diseases can lead to research achievements and encourage corresponding techniques, methods, and theories.
- A technique to analyze crop pests using UAV remote sensing is proposed in [3], utilizing the *SIFT algorithm for image mosaic and matching, resulting in successful detection of agricultural crop pests during the growing season.
- In [5] A decision support system for Late Blight disease was developed, which includes a sensor system, a cloud server to collect data, and SMS notifications to farmers.
- A review of wireless sensor networks (WSN) in precision farming for enhancing agriculture has been presented in [12], highlighting their potential to reduce cost, improve lifespan, and recover monetary losses.

HYBRID DETECTION METHODS

- A hybrid method for crop leaf disease detection using *CNN and *autoencoder combination has been designed, utilizing convolution filters of 2x2 and 3x3 to achieve accuracy up to 97.50% and 100%, respectively.
- In [13] A technique using minimum noise fraction (MNF) transformation, pure pixels endmember selection, multi-dimensional visualization, and spectral angle mapping SAM has been developed for hyper-spectral image processing of diseased tomato crops, where the first 28 signal eigen images can be used for classification, visualization, and SAM, while the rest are noise-dominated.
- *ANN methods presented in [14] aid in identifying and classifying plant diseases through the use of backpropagation algorithms, self-organizing feature maps, and *SVMs.

3.3 – DETECTION METHODS OF CROP DISEASES

3.3.1 METHOD OF DISEASE DETECTION

- Commercially, visual estimates find a disease based on the features of plant disease symptoms such as tumors, cankers, blight, galls, lesions, and damping-off with visible indications of a pathogen such as Pucciniales urediniospores, Erysiphales conidia, and mycelium.

- However, visual estimation is executed by trained experts and has been an intensive research and investigation subject.

- It should be eminent that not all plant diseases are appropriate for image-sensed detection, as some of them are deficient in identifiable properties

- Monitoring and detecting plant diseases via image sense belongs to a specific response presence that is capable of being recognized by a definite sensors system

- Out of the plants' physiological changes and symptoms that are caused by diseases, there are four kinds of damages:
  - ✓ Biomass reduction and Leaf Area Index (LAI) decrement
  - ✓ Pustules or lesions due to infection
  - ✓ Pigment systems destruction
  - ✓ Wilting: The rigidity loss because of dehydration

3.3.2 PRINCIPLES IN MONITORING PLANT DISEASES

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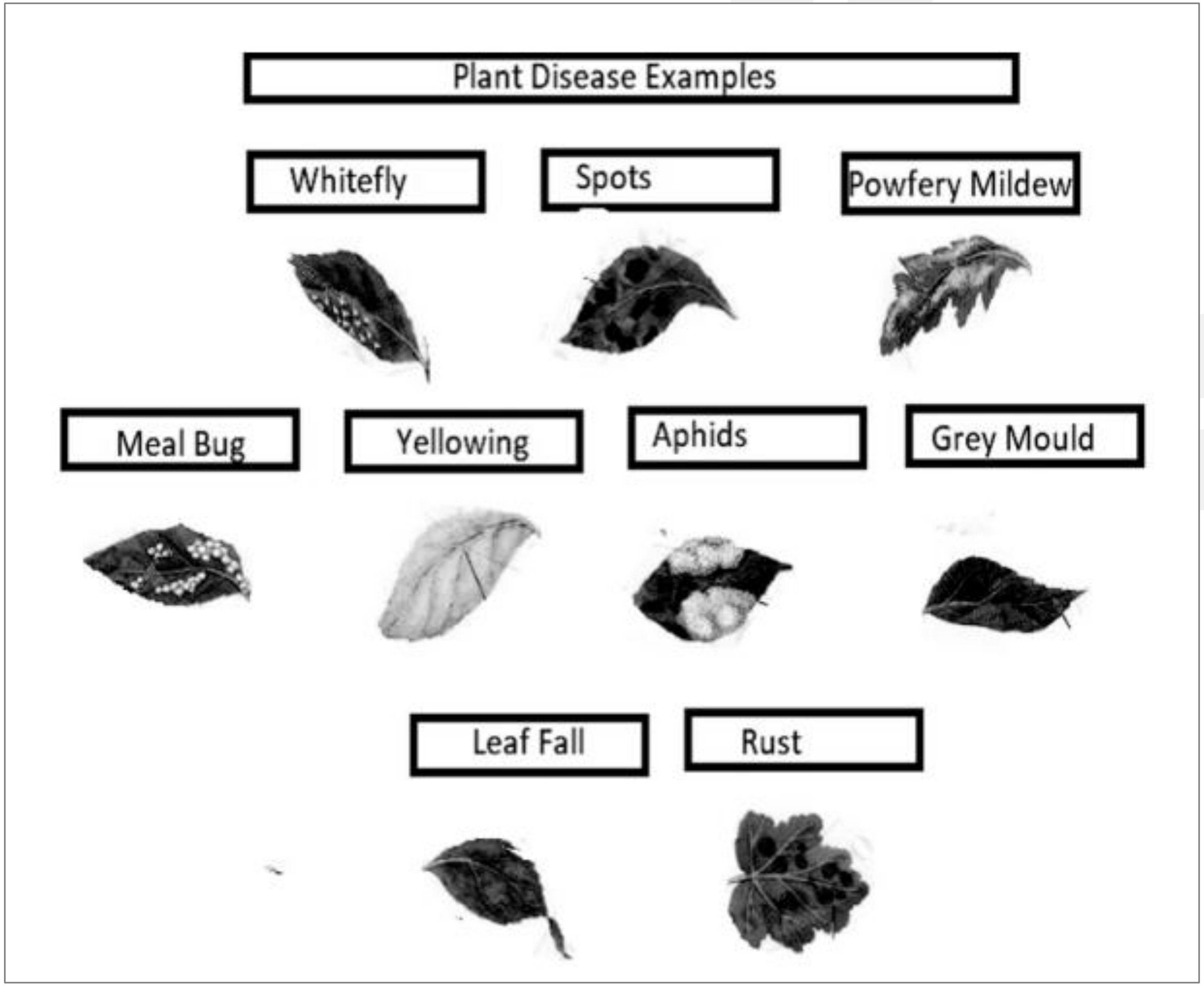

Figure 3.1 Different Types of Plant Diseases

3.3 – DETECTION METHODS OF CROP DISEASES

3.3.3 LATEST DISEASE DETECTION METHODS

- In-depth research has currently identified novel schemes for detection based on the sensors for identification, screening and plant disease quantification.
- The sensors for plants asses the imaged properties of plants within distinct areas of *electromagnetic spectrum and are capable of using data beyond the visible limits.

3.3.4 USE OF DL TO PREDICT/CLASSIFY DISEASE IN CROPS

- As indicated in Fig. 3.2, dataset is extracted from captured images
- Data cleaning process to remove redundant or noisy images
- Data is split into 80% for training set and 20% for validation set
- Deep learning models are trained from scratch using *transfer learning process
- Training and validation points are plotted to indicate significance
- Parameters of performance metrics such as F-1 scoring, and accuracy are determined for plant disease classification
- Visualization technique is used to detect localization points in images

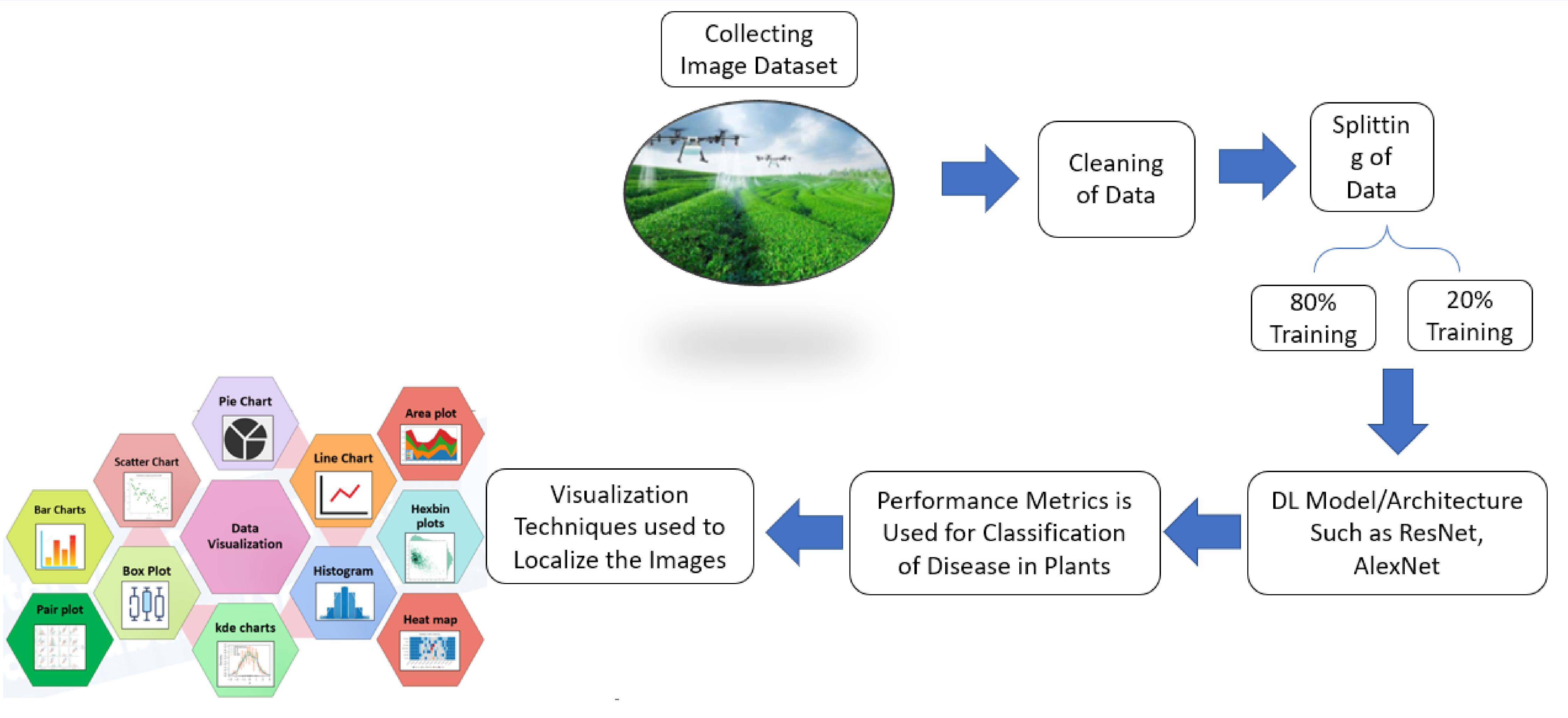

Figure 3.2 Disease prediction and classification using deep learning.

3.3.5 - IMPACT OF MODERN OPTICAL SENSORS ON DETECTION

- ❖ Different sensors are used for diagnosis and monitoring of plant diseases
- ❖ Conventional methods are the "gold standard" in plant disease detection
- ❖ Sensors allow detection of initial changes in plant physiology due to biotic stress
- ❖ Sensors measure temperature, reflectance, and fluorescence
- ❖ Thermal and spectral sensors were developed for earth remote sensing, military, aircraft, satellite, or industry
- ❖ Methods for crop disease detection: microscopic evaluation and macroscopic evaluation

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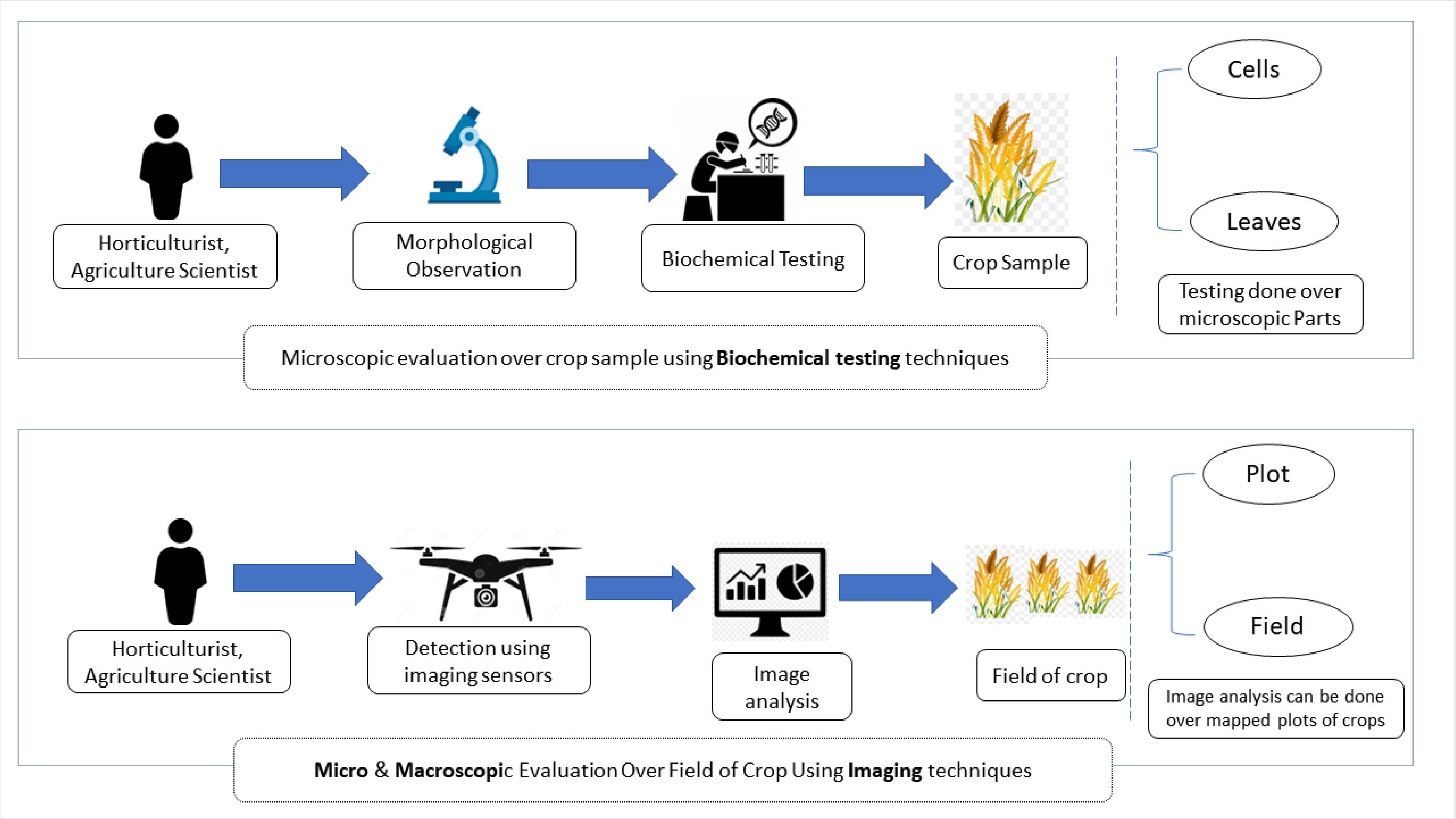

Figure 3.3 Crop disease detection techniques.

TABLE 3.1
Comparison between Microscopic and Macroscopic Evaluation Techniques

Serial No.	Microscopic	Macroscopic
1	The disease is detected by visual or morphological observation technique over samples of crop	An imaging technique detects the disease with different types of sensors on the whole plot of the crop
2	Detection accuracy depends upon the experience of agriculture scientist	Detection accuracy depends upon the data analysis & extraction technique
3	Not capable of detecting the whole plot of crop together	Capable of detecting whole plot of crop together, through aerial or land surveillance
4	By biochemical methods over cells & leaves, the disease is detected	By segmentation technique over the leaves, the disease is detected

3.4 – STRATEGIES USED FOR CROP DISEASES

3.4.1 OPTICAL SENSORS

- Optical sensors are useful for noninvasive plant disease diagnosis
- Various noninvasive and imaging sensors can be used for disease screening
- Optical sensor data can be analyzed using advanced statistical methods
- Data analysis is essential for efficient detection and diagnosis of diseases, and they involve the following steps:

1. Detection of disease at the initial stage
2. Differentiation of different diseases
3. Abiotic stress causes separation of disease
4. Quantification of disease severity

- Infrared and thermographic cameras can detect changes in crop strands and transpiration due to plant pathogens infections.
- Infrared cameras release infrared radiation in the 8-12 mm thermal infrared range, along with false-color images illustration, and each pixel is utilized at distinct spatial and temporal scales from small-scale to airborne applications.
- The leaf temperature presents a plant transpiration close correlation, which is impacted by pathogen diversity in distinct ways.
- Foliar pathogens like leaf spots or rusts consist of well-defined and local changes, while impairment by root pathogens or systemic infections generally impacts the water flow and the transpiration rate of the whole plant.
- Regional temperature variations due to diseases can be detected through thermal imaging.

3.4.2 THERMAL SENSORS

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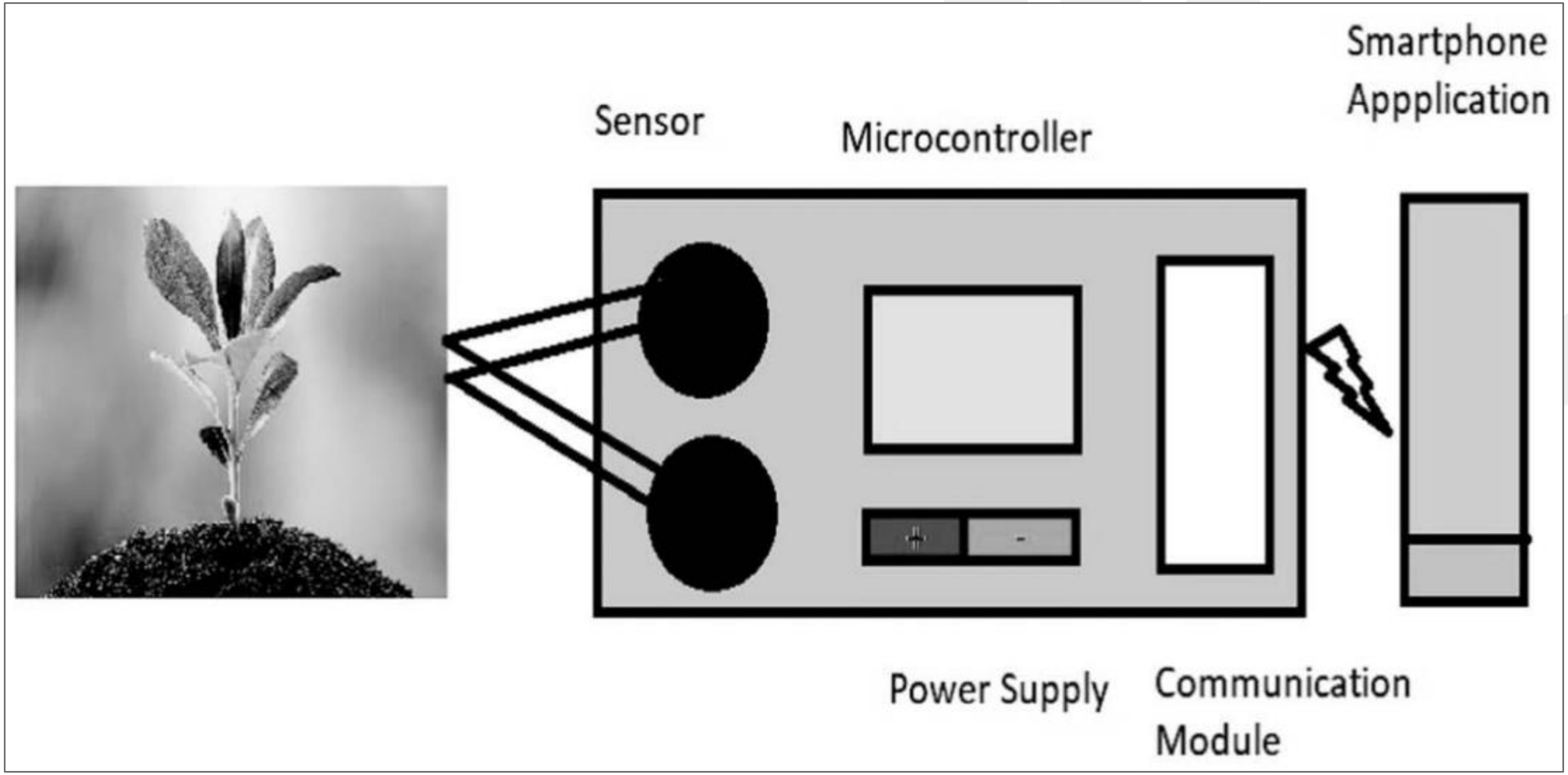

Figure 3.4 Disease prediction and classification.

3.4 – STRATEGIES USED FOR CROP DISEASES

3.4.3 HYPERSPECTRAL IMAGING IN PLANT

- Hyperspectral imaging spectroscopy was observed in the 1980s
- In plant science, image sensing is a technique for obtaining data from plants without invasive manipulation or direct contact.
- The idea has been currently growing by usage of small-scale sensing and proximal or close-range sensing of the plant material.
- These installed sensors on multiple platforms can be located at strategic points

- Hyperspectral sensors provide data in RGB and infrared wavebands
- Hyperspectral sensors have a spectral range of 350-2,500 nm and narrow spectral resolution (<= 1 nm)
- Hyperspectral imaging sensors provide spatial and spectral data for the imaged object
- Hyperspectral data can be examined as huge matrices having spatial x, spatial y, and spectral data as reflectance intensity in 3D per waveband.
- The spatial resolution depends on the object and sensor distance
- Spatial resolution has a profound impact on plant disease detection interactions
- Airborne sensors are suitable for detecting field patches with soil-borne pathogens or in terminal disease stages

3.4.4 MULTI-SPECTRAL IMAGING CAMERAS

3.4 – STRATEGIES USED FOR CROP DISEASES

3.4.5 GRAVIMETRIC SENSORS (1.)

- There are two kinds of gravimetric sensors, viz. quartz crystal microbalance (QCM) and surface acoustic wave (SAW) sensors.
- SAW sensors supply a surface wave that moves along the sensor's surface, while QCM sensors provide a stream by walking through the sensor bulk.
- The working principle of Gravimetric Sensors consists of piezoelectric sensor coating mass change because of gas absorption, which causes a variation in the frequency, resonant upon exposure to VOCs.
- Gravimetric sensors detect gas absorption through mass change.

3.4.5 GRAVIMETRIC SENSORS (2.)

- Piezoelectric substrate with interdigital input gaining electrode and transmitting electrode is used in SAW sensors.
- Odor molecules cause a variation in the frequency of the resonant piezoelectric sensor coating in Gravimetric sensors and SAW sensors.
- QCM sensors have a quartz chip covered with a gripping sensing membrane and gold electrodes attached to the base of the disk.
- QCM and SAW sensors have small size, low cost, and high sensitivity.
- The sensitivity of these sensors depends on the sensing material type and odor and film compound interaction.
- The demerits of these sensors include short lifespan and complex fabrication process.

3.4 – STRATEGIES USED FOR CROP DISEASES

3.4.6 CONDUCTIVITY SENSORS

- ✓ Figure 3.5 shows steps in prediction of plant diseases.
- ✓ Conductivity sensors are based on conducting polymers (CP) and metal oxide semiconductors (MOS) which works on variation in conductivity and resistance upon exposure principles
- ✓ The mechanisms responsible are distinct
- ✓ The sensing materials, conductive sensors substrate and electrodes are primarily the same.

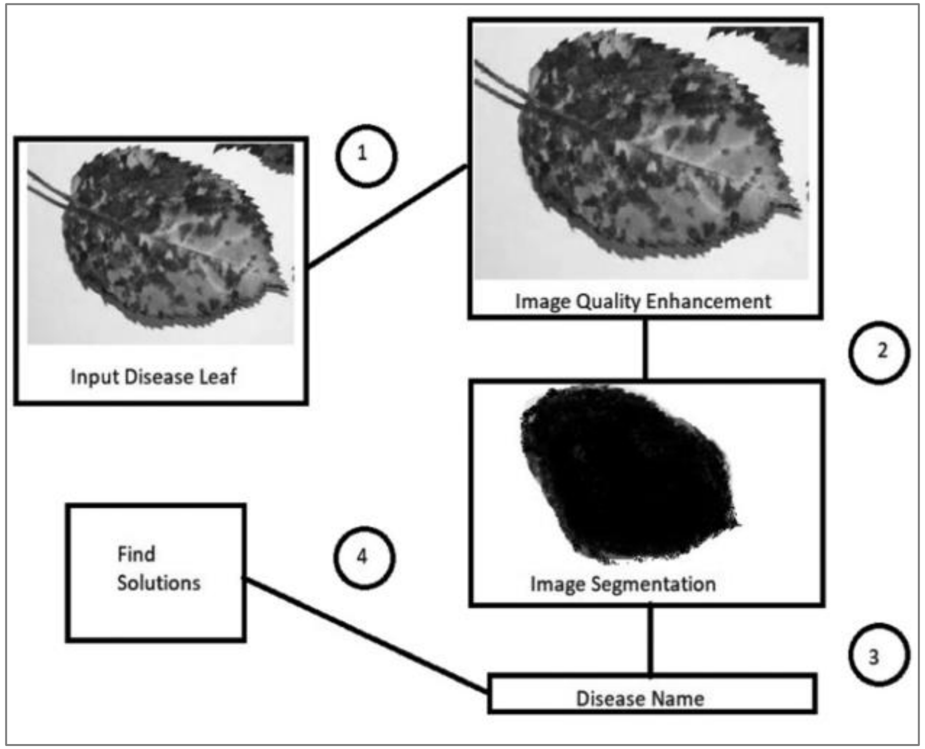

Figure 3.5 Disease Prediction Steps.

3.4.6 CONDUCTIVITY SENSORS

- ✓ MOS sensors need a heater, however, conducting polymers have lots of advantages over materials.
- ✓ Sensors developed from conducting polymers can work at room temperature.
- ✓ It is a significant merit for portable battery-powered systems as extra heater increases power consumption and minimizes the battery life.
- ✓ Most importantly, in case of array sensors, high discrimination can be attained by utilizing distinct conducting materials, as lots of categories of conducting polymers are present

3.4 – STRATEGIES USED FOR CROP DISEASES

3.4.7 CHALLENGES

- The impact of environmental temperature and humidity is a significant challenge in detection of plant diseases as sensor systems are sensitive to the weather of environment.
- This causes sensor response drift, which minimizes detection signal-to-noise ratio (S/N) of the target.
- Moreover, humidity reduces the life span of sensors, thus restricting their applications in high-frequency monitoring and assessment of long-term status of plants [3]. Besides the inspired progress that has been attained in he plant disease monitoring.
- Another challenge is the detection of field conditions. Performance of sensors in real environments requires being reviewed utilizing more extensive field trials.
- However, the environmental parameters of full and open experiments like humidity, background gas compositions, and temperature are kept changing and uncontrollable.
- Moreover, background noise produced from other objects in the environment can hide the plants' original properties caused by fungal infection, pest attacks, etc.
- Thus, a controlled atmosphere that can handle humidity temperature and gas compositions is appropriate for sensor applications. The sensor arrays' development with high selectivity

3.4.7 CHALLENGES

TABLE 3.2
Challenges in Monitoring Plant Diseases

Issues	Challenges	Trends
Detection of plant diseases at the initial stage	Various plant diseases are symptom-less or have general symptoms at the initial stage. The early symptoms of diseases tend to happen at mid- to base layers	Utilize the fluorescence, thermal, LIDAR RS, and SAR feasibility in early symptoms detection, using various multi-angular image sensing
Correctly detect a particular disease under a realistic field state	Various plants stress may happen simultaneously. Some of the crop diseases may show the same symptoms	Explore monitoring models' transfer-ability and features of uniqueness. Begin a base knowledge to help in minimizing uncertainty in the monitoring process.
Regularly analyze the disease's dynamics at a proper resolution	The RS plant system should have enough high resolution at temporal, spectral, and spatial dimensions. Worst weather causes the regular optical images acquisition	Collaborate high- resolution images using Unmanned Aerial Vehicle (UAV) images to generate a time-series RS data through a fusion between radar data and optical RS data [39]
Information and data shaping	Insufficient survey data in monitoring plant diseases. Increase the pooled data accessibility to handle model training and data mining	Set up international projects and allow data collection, experiments, ideas, and models at a global scale

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3.6 - CONCLUSION AND FUTURE SCOPE

- ✓ Early detection of plant diseases is crucial to protect crops, prevent food wastage, and save costs.
- ✓ The digital twin concept in agriculture, enabled by IoT installations, can help enhance food supply and save energy.
- ✓ Advanced and more accurate imaging methods for disease detection and prediction are needed for large land areas of crops.
- ✓ Combining deep learning and machine learning techniques can improve accuracy and efficiency in disease identification.
- ✓ Multiple sensing and imaging parameters can be used for mapping and prediction of plant diseases.

My Opinion:

The "digital twin" concept is mentioned once throughout the chapter (in conclusion section). There's slight mismatch between the Chapter Title and contents presented and the concept of DL for Disease Detection is brief and shallow. Overall, despite this mismatch, the idea presented is great and interesting as well.

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THANK YOU

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