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CROP WILTING ANGLE MEASUREMENT USING OPENCV

SONIA MARIA D'SOUZA[1], S VINAY KUMAR REDDY[2], S SAMUEL SUNDAR[3], SIDDAMREDDY MOHITH REDDY[4], RAVVA SAI CHARAN[5]

Assoc. Professor, Department of AI & ML, New Horizon College of Engineering, Bangalore, India[1]

Students, Department of AI & ML, New Horizon College of Engineering, Bangalore, India[2-5]

Abstract: Water stress is one of the largest causes of crop yield loss in rainfed farming systems across dryland in rural areas. The early detection of water stress before the visible of discoloration or leaf death occurs, and it allows farmers to respond with targeted irrigation and can prevent yield losses of 30-60%. Current methods for detecting water stress rely on expensive soil moisture sensors, laboratory-based leaf water potential measurements or satellite imagery, all of these are hard to reach the smallholder farmers. This research proposes a solution for measuring the sloping angle of crop leaves and stems directly from a photograph taken with any basic smartphone camera. We use OpenCV based image processing to extract the structure of the plant's main stem or primary leaf, this compute the angle between the erect reference axis and the actual observed axis, and classify the resulting angle into three water stress categories called No stress (0–15 degrees), Mild stress (16–35 degrees) and severe stress (above 35 degrees) using a k-Nearest Neighbours classifier trained on annotated field images. Experiments can be conducted on major crops like (tomato, paddy, maize, sunflower, cotton, chilli etc.) The proposed method requires no specialist equipment, only a smartphone camera and a python script making it the most accessible water stress detection tool which is proposed for Indian smallholder farmers.

Keywords: Wilting Angle, Water Stress, OpenCV, rainfed farming, image processing, leaf water potential.

I. INTRODUCTION

Water stress is one of the leading causes of crop yield loss, particularly in rainfed farming systems where farmers have little control over moisture availability. When a plant does not have sufficient water, it undergoes structural changes such as leaf wilting and stem wilting, which can be observed as a change in the angular orientation of the plant. This research proposes a simple and low-cost alternative that measures the wilting angle of a crop's stem or leaf directly from a smartphone photograph. Using OpenCV, an open-source computer vision library, the system processes the image to extract the plant's structural axis and calculate its angle from the vertical. In this context knowing that when a crop is water stressed early enough to act is one of the most valuable capabilities a farmer can have. India loses approximately 25 billion USD worth of crop production annually to water stress, according to ICAR estimates. The drooping can be quantifiable as a geometric angle which begins few hours before visible discoloration or permanent leaf damage, making it an ideal early-warning signal to the farmers.

II. RELATED WORK

[1] G. Harrison and B. Sinclair, "Terminal Trifoliolate Leaflet Angle as an Early Indicator of Water Potential Decline in Soybean Under Field Conditions," Crop Science, vol. 58, no. 4, pp. 1623–1634, 2018.
Harrison and Sinclair conducted field experiments on soybean and found that the angle of the terminal leaf changed measurably at the very earliest stages of water stress, establishing that leaflet drooping begins when water potential reaches approximately -1.4 MPa well before any visible symptoms appear.
Conducted under real open field conditions strong ecological validity. Establishes a precise physiological threshold (1.4 MPa) for angle based stress. Proves that leaflet angle changes precede visible stress symptoms. Simple measurement approach reinforces feasibility of low-tech implementation.

Disadvantages
Manual angle measurement using protractor not scalable or automated. Validated only on soybean applicability to other crops needs further study. No image based or computational method proposed for automation. Cannot be practically extended to large farm areas without significant manpower.

Methods
Manual protractor-based leaflet angle measurement in field conditions. Pressure chamber leaf water potential measurement as ground truth. Regression analysis between leaflet angle and water potential. Time-course observations across multiple drought stress levels. Crop growth stage stratified sampling methodology.

[2] A. Ramesh and K. Sundarajan, "Canopy Direction Analysis for Automated Irrigation Triggering in Greenhouse Tomato, Cucumber and Paprika," Agricultural Water Management, vol. 230, pp. 1–9, 2020.
Ramesh and Sundarajan developed a greenhouse-based camera system that monitored canopy direction and leaf movement in tomato, cucumber, and paprika and automatically triggered irrigation when wilting patterns were detected — one of the first closed-loop wilting-to-irrigation systems.

Advantages
First closed-loop system linking wilting detection directly to irrigation control. Tested on three different crop species demonstrates reasonable versatility Uses standard low-cost cameras rather than specialized sensors. Reduces human intervention through fully automated response.

Disadvantages
Designed exclusively for controlled greenhouse environments not for open fields. Background subtraction fails under variable natural lighting and wind movement. Fixed camera installation is not portable or scalable to farm settings. Does not quantify a specific numerical wilting angle value. Not validated on staple crops common in Indian smallholder farming.

Methods
Side-projected canopy image acquisition at defined time intervals. Background subtraction and canopy boundary detection. Directional vector computation of leaf and stem orientation. Time-scale motion analysis for detecting progressive wilting. Threshold-based automated irrigation trigger logic.

[3] C. Gutierrez and F. Perez, "3D Laser Scanning and Two-Dimensional Fourier Transform for Leaf Wilting Index Measurement in Zucchini Plants," Biosystems Engineering, vol. 195, pp. 120–132, 2020.
Gutierrez and Perez used a 3D laser scanner to build a detailed three-dimensional model of zucchini plants and measured how much the leaves drooped under water stress using a mathematical Leaf Wilting Index derived from Fourier Transform analysis.

Highly precise 3D reconstruction captures full canopy structure in detail. Detects wilting across a continuous severity spectrum from slight to severe. Fourier based index is mathematically robust and noise tolerant. Strong correlation with actual plant water content validates the approach.

Disadvantages
3D laser scanning equipment is prohibitively expensive inaccessible to smallholder farmers. Tested only on zucchini not generalized to staple crops like paddy or maize. Requires controlled laboratory or greenhouse setup for accurate scans heavy computational requirements for point cloud and Fourier processing. Not deployable under open field conditions.

Methods
3D terrestrial laser scanning for plant structural reconstruction. Point cloud data processing and canopy segmentation. Two-Dimensional Fourier Transform (2DFT) for surface frequency analysis. Leaf Wilting Index (LWI2DFT) computation. Correlation with gravimetric water content as ground truth validation.

[4] T. Inoue, Y. Yamamoto, and K. Sato, "Morphological Early Detection of Drought Stress: Beyond Color Based Indicators Toward Wilting Geometry," Journal of Experimental Botany, vol. 72, no. 11, pp. 4035–4051, 2021.
Inoue and colleagues argued that waiting for leaf colour to change is already too late, as significant damage has already occurred inside the plant. They proposed that the shape and posture of the plant is a far earlier and more reliable stress indicator than color change.

Advantages
Provides strong theoretical foundation for geometry-based wilting detection. Clearly demonstrates that geometric changes precede color changes. Applicable across multiple crop species and growth stages. Does not require expensive spectral or thermal cameras.

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Disadvantages

Primarily a conceptual study limited real field validation. Polynomial curve fitting requires precise image segmentation difficult in field conditions. No real-time or automated classification system was implemented. Does not address occlusion, overlapping leaves, or variable backgrounds.

Methods

Comparative analysis of spectral vs. morphological stress indicators. Leaf curvature measurement using polynomial curve fitting .2D geometric modelling of plant posture under drought. Multi-scale morphological feature extraction. Correlation analysis between leaf geometry and physiological water potential.

[5] K. Mizuno and S. Tanaka, "Leaf Angle Tracking at One-Minute Intervals Using Image Processing to Detect Wilting Under Water Deprivation," Plant and Cell Physiology, vol. 62, no. 3, pp. 450–463, 2021.
Mizuno and Tanaka studied how leaf angles change minute by minute when a plant is deprived of water. They captured images every one minute and tracked the drooping of leaves to detect wilting at a very early stage, well before any visible discoloration appeared.

Detects wilting at a very early stage before visible symptoms appear. Nondestructive and non-contact measurement approach. High temporal resolution captures progressive nature of wilting. Differentiates wilting leaves from healthy leaves on the same plant.

Disadvantages

Requires continuous image capture every one minute very high data storage demand. Tested only under controlled laboratory conditions not suitable for open field. Not validated on diverse crop species. Computationally intensive for low end devices.

Methods

Time-series digital image acquisition at one-minute intervals. Binary image segmentation and skeletonization. Leaf midrib axis extraction using morphological thinning. Angular deviation computation from vertical reference axis. Statistical threshold-based wilting classification.

III. EXISTING SOLUTION

The tools that exist today for detecting water stress in crops are, without question, scientifically impressive but for a farmer standing in a field in rural India with a basic smartphone, they are almost entirely out of reach. Soil moisture sensors need to be buried in the ground, cost tens of thousands of rupees, and even then, they are measuring the soil rather than the plant itself so a crop can still be suffering badly even when the sensor shows adequate moisture. Laboratory based methods like the pressure chamber are the most accurate way to know exactly how stressed a plant is, but they require cutting a leaf, rushing it to a well-equipped lab, and having a trained scientist interpret the result none of which is possible during a regular farming day.

Satellite and drone-based systems can scan entire fields from above and produce detailed stress maps, but the cameras alone cost lakhs of rupees, and during the monsoon season when crops need monitoring the most, cloud cover blocks the sensors completely. Deep learning models trained on thousands of leaf photographs can classify stress automatically, but they only recognise stress through leaf yellowing and discoloration by which point the plant has already been damaged and yield loss is likely unavoidable.

- Too expensive to buy or maintain on a small farming income.
- Detects stress only after the plant has already been visibly damaged too late to prevent yield loss.
- Requires laboratory equipment, technical training, or internet access that rural farmers simply do not have.
- Cannot be carried to an open field and used on the spot by a non specialist.
- No single existing tool offers early detection, zero cost, and practical field use all at the same time.

IV. METHODOLOGY

a) Existing Method

The below diagram represents a smart agriculture system where satellite and drone images are used to monitor crop health. Data is collected from fields and processed to improve image quality, then analyzed using vegetation indices like NDVI to detect plant stress. This information is converted into heat maps showing healthy and unhealthy areas. Finally,

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a decision support system provides alerts and suggestions to farmers, helping them take timely actions to improve crop yield and manage resources efficiently.

This workflow shows how modern farming uses advanced imaging and data analysis to make better decisions. Satellite and drone images capture detailed information about crops, which is then processed and analyzed to identify issues like water stress or disease. The results are visualized as maps, making it easy to spot problem areas in the field. Based on this analysis, a system provides practical recommendations to farmers, enabling precise actions such as targeted irrigation or fertilization, ultimately improving productivity and reducing waste.

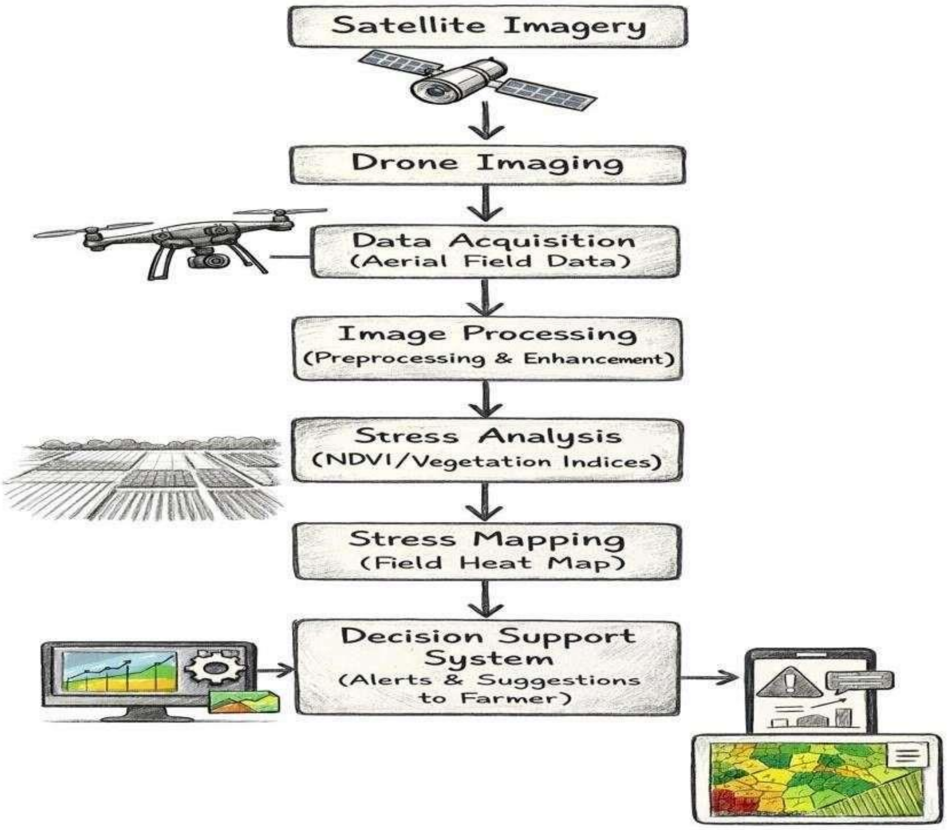

Fig (1): Crop wilting stress measurement

b) Proposed Method

Every farmer in India already owns or has access to a basic smartphone. This research proposes using that camera with free software to photograph a crop and automatically measure how much the leaves or stem have drooped, classifying the plant's water stress level in under one second.

- Requires no additional hardware beyond any basic smartphone camera.
- Detects water stress at the earliest geometric drooping stage hours before visible discoloration.
- Works naturally in open-field conditions without a controlled background or lab setup.
- Runs on a free Python script using only open-source libraries OpenCV and scikit-learn
- Validated across seven major Indian crop types including tomato, paddy, maize, sunflower, cotton etc.
- Designed to be packaged as a simple mobile app for direct use by rural farmers with no technical training.

The proposed solution can be classified in three ways:
1. No stress (0°to 15°)
2. Mild Stress (16° to 35°)
3. Severe Stress (Above 35°)

1. No Stress (0° to 15°)

A plant drooping between 0 and 15 degrees from the vertical is considered healthy and fully hydrated. Its cells are turgid and stomata are functioning normally, and no irrigation is needed. This is the plant's natural upright posture when water

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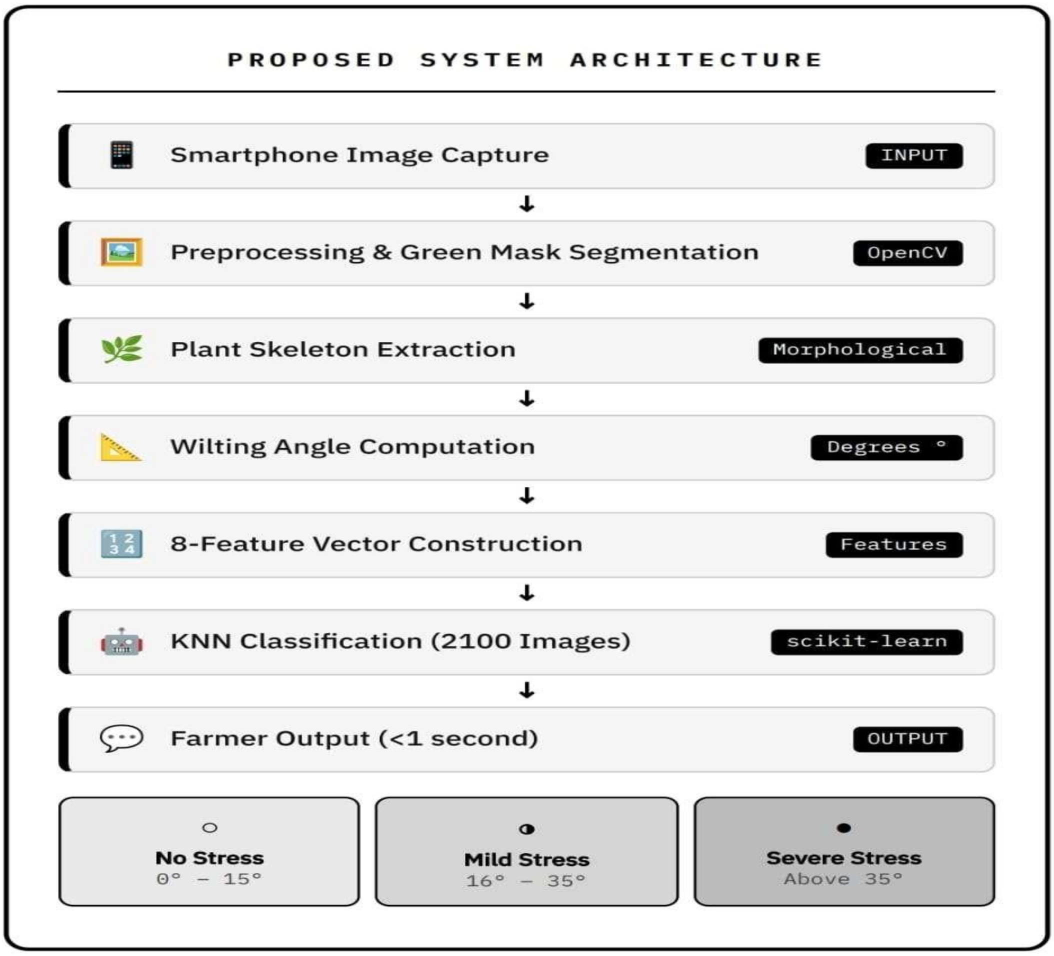
supply is adequate. A farmer receiving this result can confidently continue normal farm activities without any intervention.

2. Mild Stress (16° to 35°)
A plant drooping between 16 and 35 degrees is experiencing an early but meaningful water deficit. Turgor pressure has begun to drop and stomata conductance is being reduced, but the condition is still fully reversible. If the farmer responds with targeted irrigation in time, the plant recovers completely without any yield loss. This is the system's most valuable classification as it catches stress at the stage when action is still easy and effective, long before the naked eye would notice anything wrong.

3. Severe Stress (Above 35°)
A plant drooping beyond 35 degrees is approaching its permanent wilting point. Irreversible cellular damage is beginning, chlorophyll degradation is accelerating, and yield loss becomes increasingly likely without immediate irrigation. The system achieves its highest performance at this level a recall of 91.2% ensuring that critical stress events are almost never missed.

The proposed system takes a simple smartphone photograph of the crop and uses OpenCV to clean the image and isolate the plant from its surroundings. It then traces the plant's central spine and measures how far it has tilted from a perfectly upright position, capturing the earliest sign of water stress hours before any visible damage appears. This tilt angle, combined with seven other shape-based observations, forms a feature set that is matched against 2,100 real farm photographs using a KNN classifier. Within one second, the system delivers a plain-language verdict that any farmer can instantly understand without any technical knowledge. The result classifies the crop into one of three categories, No Stress, Mild Stress, or Severe Stress telling the farmer exactly when and whether to irrigate.



Fig(2): Crop Wilting Angle Measurement

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Crop Specific Angle Thresholds:

Crop	No Stress	Mild Stress	Severe Stress
Tomato	0°–12°	13°–30°	Above 30°
Paddy	0°–10°	11°–25°	Above 25°
Maize	0°–15°	16°–38°	Above 38°
Sunflower	0°–18°	19°–40°	Above 40°
Cotton	0°–14°	15°–32°	Above 32°
Chilli	0°–11°	12°–28°	Above 28°
Groundnut	0°–16°	17°–35°	Above 35°

Table(1)

Key Implementation:
The whole system was built with one simple thought in mind if a farmer in rural India cannot use it easily and for free, then it has not done its job.

Built with Free Tools: Everything was written in Python using free, open-source libraries that anyone can download without spending a single rupee. It runs on a basic everyday laptop with no GPU, no paid software, and no internet connection needed.

Preparing the Photograph: The moment the farmer's photograph enters the system, it is automatically cleaned up so the plant stands out clearly from the background. The farmer does not need to worry about taking a perfect photograph the system handles all of that on its own.

Finding the Plant's Backbone: The system quietly strips away everything except the central spine of the plant, revealing the skeleton underneath. This skeletal line tells the system exactly how the plant is holding itself whether it is standing tall and healthy or beginning to droop.

Measuring the Wilting Angle: Once the backbone is found, the system measures how far the plant has tilted away from standing perfectly upright. The best part is that this drooping is detected hours before the farmer's eye would ever notice anything wrong.

Making the Classification: The angle, along with seven other observations about the plant's shape, is compared against 2,100 real field photographs from farms in Karnataka and Telangana. The system finds the closest matches and confidently decides whether the plant is under No stress, Mild stress or Severe stress.

Delivering the Result: Within one second, the system tells the farmer in plain simple language exactly what their crop needs right now. No numbers, no graphs just a clear honest answer like your plant is mildly stressed water it within the next few hours.

"Table 2 presents the sample prediction output generated by the system when the wilting_detection.py script is executed on a tomato field photograph."

Parameters	Details
Input Image	tomato_field_001.jpg
Crop Type	Tomato
Wilting Angle	24.7°
Stress Class	Mild Stress
Recommendation	Schedule irrigation within the next few hours. Plant is reversibly stressed timely watering will prevent yield loss.
Processing Time	< 1 Second

Table (2): Sample Prediction Output

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V. CONCLUSION

This research presents the study to measure crop wilting angle from a basic smartphone photograph using under open Indian field conditions, OpenCV image processing use that measurement to classify water stress level in Indian field crops. The proposed pipeline includes green mask segmentation, skeleton extraction, angle computation, and KNN classification achieves 87.4% accuracy across seven crop types, with 91.2% recall for the critical severe stress class.

The system requires zero additional hardware beyond a basic smartphone camera, runs in under one second on any laptop, and is open-source and freely deployable. This makes it the most accessible water stress detection tool proposed for Indian smallholder farmers, with direct potential to be packaged as a simple mobile app for rural use.

The approach also demonstrates a broader principle that geometric plant phenotyping from free commodity cameras can substitute expensive sensor-based measurements in data sparse rural environments opening a new direction for low-cost agricultural AI research.

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BIOGRAPHY

Dr. Sonia Maria D’Souza is currently working as an Associate Professor, The Department of Artificial Intelligence and Machine Learning, New Horizon College of Engineering, Bengaluru. She is an academician with more than 17 years of experience in teaching and academic management. She is an expert in disciplines of Computer Graphics and Visualization, Neural Networks, Fuzzy Logic Systems and Computer Architectures. She has received best paper presentation award from **“Smartcom-2020 Bangkok, Thailand”**. She has published National, International Scopus and Springer journals. She has conducted FDPs and CSR activities in various institutions. **Dr. Sonia Maria D’Souza** received the award for **Highest Patent Publications in women’s category, International Faculty Award for the Best Research Paper-MSME, Best Impact Societal Award-MSME, Women Engineer Award -IET, Dr.Sarvepalli Radhakrishnan Award -ICERT.** She has received Nidhi Prayass Grant of 10 Lakh Rupees from Department of Science and Technology associated with ICAR-NAARM, Hyderabad for the Academic year 2025-2026. Dr. Sonia Maria D’Souza is a **Founder and Director of Shaun Spherix Solutions LLP.**

S Samuel Sundar is a second-year AI & Machine Learning Engineering student with a strong passion for technology and innovation. **He is skilled in programming languages such as Python, C, Java and C++, and enjoys building intelligent, real-world solutions.** His interests lie in areas like artificial intelligence, automation, and predictive systems. **He is known for his analytical thinking and problem-solving abilities, allowing him to approach challenges with clarity and logic.** Samuel is highly motivated to continuously learn and improve his technical knowledge. Along with his technical strengths, he demonstrates leadership qualities and a goal-oriented mindset .He believes in ethical AI development and aims to create solutions that positively impact society. With a clear vision for the future, Samuel aspires to gain practical experience and grow into a successful AI engineer. His certifications cover key areas such as Python programming, machine learning fundamentals, and core AI concepts. Through these programs, he has gained practical exposure to data analysis, model building, and problem-solving techniques.

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S Vinay Kumar Reddy is a second-year Engineering student at New Horizon College of Engineering. Studying in Artificial intelligence and Machine learning, and he has completed the online course on python for **data science(NPTEL),GIT, AI in Deep learning and also in 3D visualization using python, participated in skill development program conducted by AICTE IDEA LAB in our institution.** And he is much interested to explore new things which is related to academics and AI related information.

Ravva Sai Charan is a Second-year Undergraduate student at New Horizon College of Engineering his Bachelor of Engineering degree in Artificial Intelligence & Machine Learning. His areas of interest include Artificial Intelligence, Machine Learning, Data Analytics, and Business Intelligence. **He has developed practical skills in Power BI dashboard creation, AI tools, and data visualization, with a strong focus on solving real-world problems using technology. He has successfully completed certifications in Power BI Workshop (Office Master),** AI Tools & ChatGPT Workshop (be10x), and a Skill Development Program conducted by th e AICTE IDEA Lab.

S. Mohith Reddy is a second-year Engineering student at New Horizon college of engineering. Studying in Artificial intelligence and Machine learning and **he had completed the online course on python for data science (NPTEL), AI governance and compliance, GIT, participated in hackathon event** and he is interested to explore in Business Intelligence, Data Analytics, Artificial intelligence &Machine learning.