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Farm Smart: Empowering Agriculture and Greenhouse Farming through Artificial Intelligence and IoT Integration

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Abstract: We present an innovative AI-powered irrigation and plant nurture system designed to revolutionize modern agriculture and greenhouse farming. Our system meticulously monitors plant growth and health, responding dynamically to real-time conditions. It provides comprehensive oversight of vital growth factors, including soil and ambient temperature, humidity, moisture, soil pH, and nutrient content, leveraging a vast array of data sources. This data is seamlessly relayed to the user interface, empowering farmers and gardeners with actionable insights. Advanced algorithms use this data to calculate precise nurturing requirements, optimizing plant health and crop yields.

Our journey in developing this smart farming system, intertwined with IoT technologies, has been both enlightening and promising. Despite current limitations in plant detection and disease identification, the future shines with possibilities and advancements in agricultural practices. The system promises efficiency and intelligence in farm management through IoT devices, data science, and AI algorithms, revolutionizing crop yields and sustainability. By empowering farmers with user-friendly interfaces and real-time data, it optimizes resource management and reduces labor.

Addressing environmental challenges like water scarcity and climate change, as well as socioeconomic issues arising from produce price inflation due to population increase and high demand, our system fosters sustainable agriculture with energy optimization and precision irrigation. This innovative approach marks a significant step forward in promoting a greener, more efficient, and sustainable future for agriculture. Our project embodies the fusion of cutting-edge technology and sustainable agriculture, offering a promising solution to enhance plant growth, conserve resources, and promote a greener future.

Keywords: Agriculture, Greenhouse farming, Artifcial intelligence, Sustainable farming

1. Introduction

Agriculture has catapulted humans to the apex of life on earth since the Neolithic revolution. As warmer and milder climates developed and the ice started melting after the last glaciation, other mammals that relied heavily on grazing and eating plants such as the megaherbivores, started to die out [1] humans rose out of this big shift, this will be a recurring theme as history tells, as each major advance in agriculture was accompanied by an increase in population growth rates [2]. as the conditions were right for the domestication of plants and animals; both turned into great sustenance sources as a result of agriculture [3]. During the Neolithic Revolution, agriculture changed from hunting and gathering to farming, beginning about 10,000 BCE [4]. Over time, innovations in equipment, irrigation, and crop varieties evolved. Crop rotation was first implemented in the medieval era [5]. according to historical evidence, agriculture emerged and spread from and across various parts of the world approximately 10,000 to 5000 years ago [6]. Before the invention of agriculture, hunting, and gathering were the only food procurement strategy practiced ever since humans emerged some 7 million years ago. However, the transition to agriculture led humans to the start and rise of civilization and the new lifestyle of procurement of material wealth has revolutionized the human mindset in contrast with the Neolithic hunter and

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gatherer mindset [7], thus it has rightfully gained the title, the Neolithic Revolution [8].

With growing and rising technologies, agriculture also has changed, specifically farming, in many ways. Artificial Intelligence technologies are rapidly making their way into agriculture a 5 trillion-dollar worldwide industry [9]. Modern problems require modern solutions, not yesterday's technology, As the world gets ever so large with population increase, agriculture is more important than ever [10], with limited resources the only way forward is with sustainable farming [11], however with this growth comes complexity, utilizing this technology can help farmers to tackle issues and solve problems such as monitoring of soil and growing conditions, organizing data for farmers, and helping with workloads.

A. Literature review

New technologies are driving change in the agriculture sector, which appears highly promising as it will allow this vital sector to advance to a higher level of farm profitability and production [12] Because of the high population density, supply, and demand struggle to keep up. The population of the globe is predicted to rise to 9.8 billion in 2050, a 25% increase from its current size. Most of the population growth is likely to take place in developing nations [13], The third wave of the modern agricultural revolution, following mechanization and the green revolution's introduction of genetic modification to agriculture, is marked by the emergence of precision agriculture. This paradigm shift emphasizes applying inputs precisely when and where they are needed; to save precious resources like water and keep costs down, a concept currently being refined through the integration of advanced farm knowledge systems enabled by the availability of vast amounts of data [14]. Amidst this wave of innovation, our system stands out as a collection of comprehensive and integrated solutions for enhancing agricultural practices. In contrast to standalone mobile applications for remote monitoring [15] described in existing research, our project goes beyond surface-level monitoring, delving into the intricate details of plant growth, health, and environmental monitoring. By utilizing the remote capabilities of several IoT technologies, data science, and AI algorithms. Adding a layer of autonomy to the process of farming by utilizing the data collection of several vital variables, soil moisture for example, is a significant factor influencing the physics, chemistry, and biology of soils. Consequently, variations in soil properties and processes caused by moisture have an impact on aboveground ecosystems in agricultural settings [16] Several vital variables contribute to the success of growing produce, and keeping track of them can be a difficult task therefore our system focuses on addressing such pain points for farming and optimizing it. our system empowers farmers with actionable insights and real-time alerts, facilitating informed decision-making and precise resource.

management. Through this holistic approach, our system not only promises to optimize farm profitability and production subsequently contributing to the broader goals of sustainability and environmental stewardship in agriculture,

Table 1 illustrates a technical review on smart systems that integrates to farm researchers.

Studies	Issue (Problem)	Method	Advantage	Disadvantage	Ref.
Design and Implementation of Smart Farming in Korea Electronics Technology Institute	IoT-based Agriculture	IoT-based Agriculture	Enables easy extension for new devices, facilitates horizontal smart farm platforms.	Reliance on IoT technology, minimal autonomy	[17]
Soil moisture in USA by AquaSpy	Soil Moisture Sensing	Electromagnetic Sensors (TDR315, CS616, CS655, Hydra Probe2, EC5, 5TE, Teros12, Vector Probe)	Provides continuous soil moisture measurement	Interreplicate variability in static assessments, increased variability during rainfall, challenges in confident value	[18]
In-field automatic observation of wheat heading stage using computer vision	Growth stage information	Computer vision technology	Efficient, continuous, non-destructive observation of wheat heading stage	Wheat plants with low spatial resolution pose challenges	[19]
AI-based modeling and data-driven evaluation for smart farming-oriented big data architecture using IoT with energy harvesting capabilities	IoT Energy Harvesting in Smart Agriculture	Big data, IoT components, Knowledge-based systems	Clean installation, Low maintenance, Automatic configuration	Limited power, Dependence on environmental factors, Initial setup complexity	[20]

Which underscores the potential of IoT (Internet of Things) technologies and Artificial Intelligence has to revolutionize agriculture, especially greenhouse farming, and shows key discrepancies that our system aims to fill and highlights the urgent need for innovative solutions to address historical challenges in greenhouse farming, traditional farming, and agriculture in general.

B. problem statement

The focus of our system is to find the main issues and challenges of farming and solve them. The main issue with farming is the lack of an integrated interface to solve specific issues. Among all agricultural challenges, the primary concern is inadequate crop quality or yield, the root of which is from issues affecting plant health, yield optimization, water usage [21], and overall quality [22], for example, crops benefit from nitrogen supplementation [23] especially when growing in a greenhouse. Such issues have grave consequences such as the effect of plant health and yield have on food security [24] and the implication irrigation has on soil [25], affecting not just plants as mentioned before. The hypothesis of this study can be titled “How to build a system to reduce the damage and disadvantages of farming while optimizing and boosting crop yields and solve the point of pain in previous concerns which was Inadequate crop quality and yield”.

C. Approach

The focus of our system is to identify the main issues and challenges in farming and provide effective solutions. The primary problem in farming is inadequate crop quality and yield. To address this, our system targets key factors such as plant health, yield optimization, water usage, and quality. By concentrating on these critical areas, the system aims to promote more effective, sustainable, and financially feasible farming practices.Farm Smart includes both software and hardware components designed to monitor plant leaves and soil health. It utilizes sensors connected to an Arduino to gather data on soil moisture, temperature, pH, and nutrient levels. This data is then transmitted via the internet to a mobile application, providing real-time insights and recommendations to farmers.Additionally, Farm Smart is equipped with capabilities to detect various stages and types of blight, including leaf blight, early blight, and late blight, across a range of plants such as potatoes, tomatoes, corn, and carrots. This comprehensive monitoring and diagnostic system enables farmers to take timely actions to prevent disease spread and mitigate damage.The integration of AI and IoT in our system allows for precise control over irrigation and fertilization, optimizing water usage and ensuring plants receive the necessary nutrients. By improving plant health and optimizing resource management, Farm Smart not only enhances crop quality and yield but also contributes to sustainable farming practices. This innovative approach provides farmers with the tools they need to achieve better outcomes and ensure the long-term viability of their farming operations.

2. METHOD

Before discussing acquisition, UI (user-experience) is imperative as most farmers are typically not tech-savvy, this can be solved by providing a user-friendly website and mobile application that is connected to sensors, for this purpose, actions were needed to start accordingly to plan the phases as shown in Figure2.1.

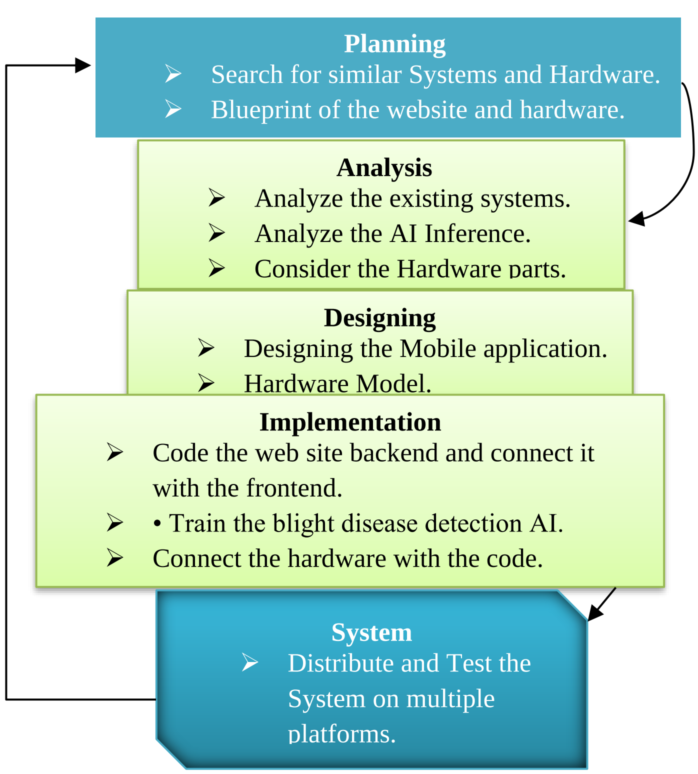

Figure 2. 1 Main Framework

A. *Planning and collecting phase*

The first step was to search for existing smart farming projects to check for areas of discrepancies and to gather information on how to create an automated system That includes a responsive website and user-friendly mobile application, as which technology, sensors, AI algorithms, and language to use and what should be included in the system to make it more efficient and intelligent.

One example that highlights the importance of planning the best hardware configuration combination was deciding which hardware to choose. for measuring the internal temperature of the greenhouse, we had to pick the most feature-packed sensors so instead of using a standalone temperature sensor and a humidity sensor we opted for a sensor that had both (DHT22) as having an extra sensor means extra wiring and extra mounts this would increase the complexity and the chances of faults and increasing reliability and helping our goal of reducing human involvement.

hardware	Ph & NPK soil sensor	**DHT**22	Arduino uno	water pumps	humidifier
QNT	1	1	2	3	1

Table 2.1 Core hardware

• Collect the hardware Components mentioned in Table 2.1.
• Train the blight disease detection AI.
• design and build the Mobile application.
• design and build the hardware.
• Connect All the hardware components to the user interface (mobile app).

B. *Analysis phase*

We had to investigate the current farming projects to find similarities with our project and locate and optimize weak points on both the software and hardware sides. So that we can decide which parts are the best for our use-case and more reliable in farming environments. Under the many difficult conditions that farmers usually face.

C. *Designing phase*

1) *Designing the Software*

the aim of the Design is to be user-friendly and work for different platforms REACT.JS is the language that we chose for building the entire website and mobile application. As a structure, home.js (homepage) takes the lead for the whole system, and for design, we have used Material-UI. On the home page, here we see one of the diagrams we used throughout the design phase; the submit image button when uploading an image subsequently the website will process it and give feedback about the illness and the percentage of it & extra information from other sensors for example Temperature, potential of hydrogen and humidity the Figure 2.2 explains the Front end.

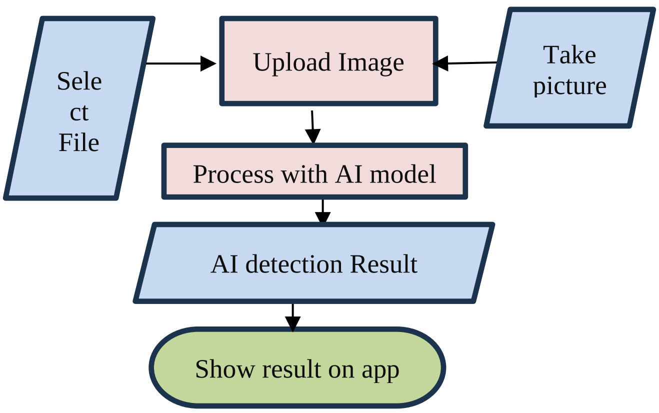

Figure 2.2 picture uploading process

2) *Designing the hardware*

The Design aims to be fast and work with the different sensors. We chose Arduino as our primary platform for building a significant portion of the system.

a) Soil Ph&NPK Sensor: The Soil Ph Sensor has 4 pins as it needs to be connected to the RS485 or MAX485 Module and onwards to the Arduino as shown in Figure 2.3.

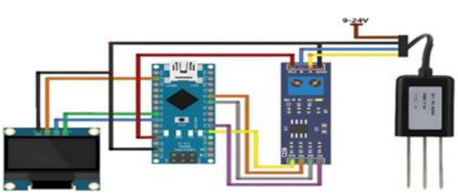

Figure 2.3 ph circuit

as for interfacing the Soil Ph Sensor with Arduino and retrieving Soil Ph values from the Sensor via Modbus command utilizing this datasheet Table 2.2 for correct addressing.

Address code	Function Code	The effective number of bytes	Data area	Second data area	Nth data area	Check code
1bit	1bit	2bit	2bit	1bit	2bit	2bit

Table 2.2 Datasheet

the initializing code will be something like this:

const byte ph[] = {0x01, 0x03, 0x00, 0x00, 0x00, 0x01, 0x84, 0x0A};

this process is repeated to retrieve the other readings such as the temperature and moisture by changing to the assigned address based on the manufacturer's data sheet.

b) Ambient Temperature and Humidity sensor (DHT22):

The DHT22's implementation is much more straightforward compared to the soil pH sensor, it employs a capacitive humidity sensor and a thermistor to measure the ambient air conditions, providing a digital signal via the data pin without requiring any analog input pins. the left pin connects to 3-5V power, the middle pin to the data input pin, and the right pin to the ground as shown in Figure 2.4 the Sensor Output is shown in Figure 2.4 DHT22 (b)

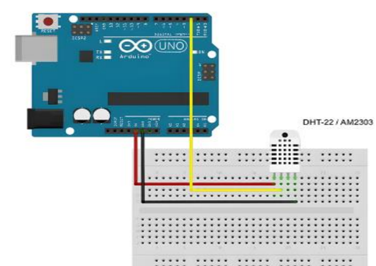

Figure 2.4 DHT22 (a) circuit

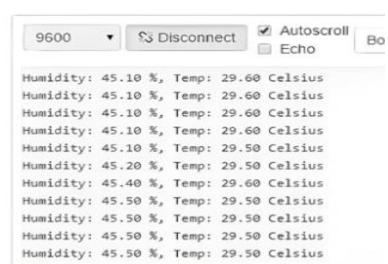

Figure 2.4 DHT22 (b) serial output

Data from both sensors provides freedom in using the data for various purposes, the method of choice was to extract the data mentioned, from the serial output of the sensors and using commas to separate each reading. Data can be easily saved in Firebase databases, CSV files, and plain text (.txt) files afterward using this method. This method makes it simple to parse serial data in Processing, PHP, and many other computer languages and scripts.

The db_connect.php, is the main bridge that enables us to transfer the data read from the Arduino to the database and from there to the website where it is displayed for the user to help visualize what is happening, we undertake three primary tasks in this file. First, we print the serial data and its label and then send it to the MySQL database. which is mostly for debugging. The code is constructed so that the sensor data is first divided into an Array and then sent to the MySQL database. Furthermore, by adding the "output. print" phrase to the array members, we can save the data to a text file.

D. Implementation phase

This phase discusses the software side where first, we write algorithms and train the models then connect it to the server using node.js, and finally to the hardware side the build of which we covered. The hardware has a connection to the software side so we can have feedback on the application. as it’s shown in the Figure 2.5.

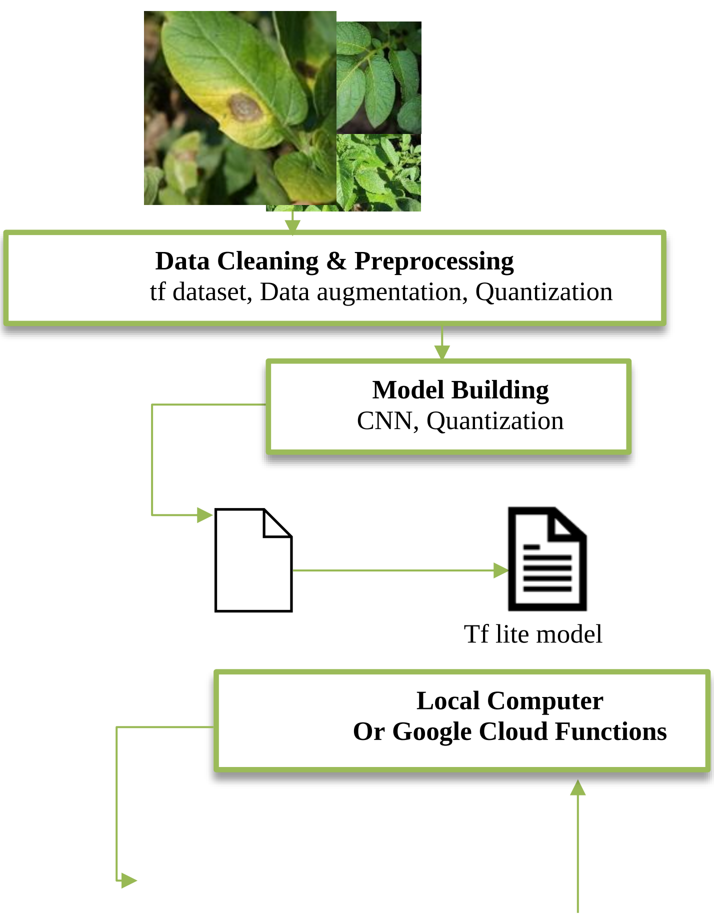

Figure 2.5 General system implementation

E. Testing phase

Testing the system is one of the most challenging phases because it must be done through the entire process of creating the system which contains both hardware and software together. regular testing on different platforms with many conditions to find any issues and resolve them to meet our criteria and rinse and repeat until we achieved a Viable, more streamlined System.

The main steps to our testing were:

1) *Testing planning:*

The main thought process through this step was to not affect already existing processes when introducing a new one. For the project to be better after the implementation of the new process, we had to keep in mind the scope of our project as any overly ambitious efforts may result in scope creep and delays, potentially leading to a dead end.We began by defining clear, measurable objectives to ensure the new system could be seamlessly integrated without disrupting current farming practices. A detailed risk assessment was conducted to identify potential points of failure and develop mitigation strategies. Additionally, we created a comprehensive testing framework to evaluate the system's performance under various environmental conditions, ensuring its reliability and robustness.To maintain the project’s scope, we adopted an iterative development approach, allowing us to implement and test small, manageable components incrementally. This strategy helped us to detect and resolve issues early, ensuring each component met the desired standards before progressing to the next phase.

Furthermore, stakeholder involvement was crucial throughout the testing phase. Regular feedback from farmers and agricultural experts provided valuable insights, helping us fine-tune the system to meet real-world needs. This collaborative approach ensured that the final implementation not only enhanced current farming processes but also aligned with the practical requirements and constraints of end-users.

By focusing on incremental improvements and maintaining a clear scope, we were able to introduce innovative solutions without overwhelming existing systems, thus ensuring a smooth transition and successful project outcomes.

2) *Regression testing:*

As mentioned before some features were critical to being implemented while some were not so much, thus consistent regression testing is paramount to not result in critical processes being affected negatively by the change for example using an rs485 Modbus to a USB modem is better than using a TTL to rs485 because the connection to the circuit becomes less complex and frees up space and connecting USB enables us to recalibrate the ph sensor if we replace the rs485 USB Modbus with the ttl to rs485 chip we will lose the ability to calibrate and therefore regress in terms features and capability of the system. Hence the importance of regression testing.

3) *Performance testing:*

Two important metrics that need to be met for our criteria were speed and file size optimization. There is considerable room for improvement, particularly in the software side, specifically within the disease detection module. One notable consideration was the transition from running the TensorFlow Serving (tf serving API) locally to deploying it on a Docker server. While Docker appealed to some team members due to its flexibility in model interchangeability, it did impact the speed and file size that could be processed within acceptable timeframes. However, we have decided to leverage Google Cloud Platform (GCP) to host TensorFlow Serving, as it offers faster processing speeds and supports larger file sizes, crucial for our end product. Nonetheless, as we are currently in the testing phase,

we must initiate comprehensive performance testing protocols. This entails conducting rigorous benchmarking exercises to quantify the exact impact of switching from local TensorFlow Serving to a Dockerized environment on both speed and file size handling capabilities. By systematically measuring these metrics across different scenarios and under varying loads, we can pinpoint potential bottlenecks and fine-tune our software algorithms accordingly.

Moreover, integrating automated testing frameworks will be pivotal in ensuring consistent and reproducible results throughout the testing phase. This approach not only enhances the reliability of our performance assessments but also facilitates quick iteration and validation of optimizations made to enhance speed and manage file sizes effectively.

Additionally, collaborating closely with stakeholders from the disease detection domain will provide valuable insights into real-world performance expectations and user requirements. This feedback loop will be instrumental in refining our testing methodologies and validating that our optimizations align with practical application scenarios, thereby reinforcing the robustness and reliability of our software solution.

RESUALT AND DISCUSSION

F. Dataset

Here we can see some of the images with their respective annotations grouped up in a batch, by using batches as you can observe in Figure 3.1, we can introduce some randomness and noise into our data, which can prevent overfitting and improve generalization.

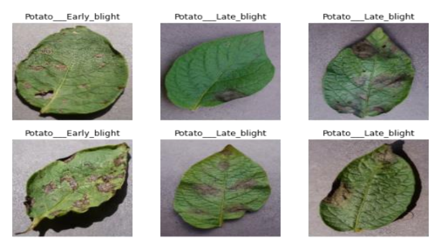

Figure 3. 1 image sample

After creating layers for resizing, normalization, and data augmentation, we incorporate these layers into the model architecture, which comprises a Convolutional Neural Network (CNN) coupled with SoftMax activation in the output layer. The SoftMax activation function transforms raw output scores (logits) into a probability distribution over multiple classes. Subsequently, we compile the model using the Adam optimizer. Adam (Adaptive Moment Estimation) is a well-known optimization algorithm that integrates concepts from momentum and RMSProp algorithms. It dynamically adjusts the learning rates for each parameter, leveraging estimates of both the first and second moments of the gradients. This facilitates faster convergence and enhanced generalization in model training.

G. Training results

After training the model we can Visualize the Results using Plotting the Accuracy and Loss Curve in Figure 3.2 and after creating the function we can see the prediction on new unseen data in figure 3.3.

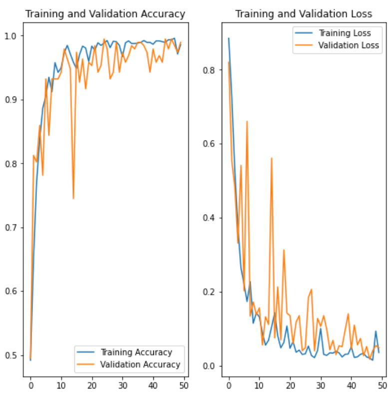

Figure 3.2 Training and Validation plot

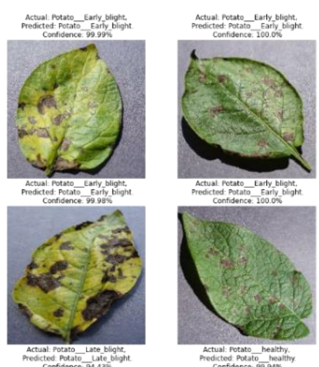

Figure 3.3 inference samples

3. CONCLUSION

In conclusion, our journey in developing an innovative smart farming system, intertwining IoT technologies, has been enlightening and promising. We've delved into intricate details to create a system aiding farmers while aligning with sustainability needs. As we conclude, the future shines with possibilities and advancements in agricultural practices.

Although it's currently limited by the type of plants it can detect and the type of plant diseases, our system nevertheless promises efficiency and intelligence in farm management through IoT devices, data science, and AI algorithms. This revolutionary approach is set to enhance crop yields and sustainability significantly. By empowering farmers with user-friendly interfaces and real-time data, our system optimizes resource management and reduces labor.

Addressing environmental challenges such as water scarcity and climate change, our system also tackles socioeconomic issues arising from produce price inflation due to population growth and high demand. It fosters sustainable agriculture through energy optimization and precision irrigation. Moreover, our system's ability to provide actionable insights and timely recommendations ensures that farmers can make informed decisions, improving overall farm productivity and sustainability.

We envision a future where such smart farming systems are integral to global agricultural practices, leading to a more resilient and efficient food production system. Continued advancements in technology and further research will expand our system's capabilities, allowing it to support a broader range of crops and detect more plant diseases. As we move forward, our commitment to innovation and sustainability remains steadfast, driving us to refine and enhance our system to meet the evolving needs of farmers and the agricultural industry.

In summary, this project represents a significant step toward the future of farming, where technology and sustainability go hand in hand to address the pressing challenges of our time.

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