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Assessment of IoT Enabled Robotic Systems for Enhancing Efficiency in Smart Farming: Analysis and Implications for Sustainable Agriculture and Climate Change Mitigation

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Abstract
In this era of science and technology, we are still using conventional mechanized farming where the efficiency is too low. The need for food and agriculture is increasing globally, but we have not seen any revolution in IoT-based farming. In this paper, we analyzed data on a custom-made robot, 'Agrover.' This paper shows how IoT-based robotic farming can revolutionize the highly efficient farming style and emits 0% carbon.

The methodology involved creating a prototype of Agrover and adding essential features such as sprayers, seeders, and various sensors. Data collection and analysis focused on a moisture sensor at a hybrid tomato-pepper farm in Demra, Dhaka, Bangladesh, where we recorded 8-bit moisture values and converted them to percentage moisture content over ten hours and used Python code to produce a graphical representation of the pattern in moisture content variation, which is an important factor for growing crops.

Including solar panels and lithium-ion batteries ensures zero carbon emissions, enhancing sustainability. This research demonstrates the potential of combining advanced technologies with smart farming practices to address the challenges of food security, health, and environmental sustainability in agriculture.

Introduction
The global population has risen remarkably within the last few centuries and is expected to grow even further. [1] It has grown rapidly from approximately 1 billion in 1800 to 8.1 billion in 2024. [2] The population growth rate is approximately 1.1% per year. [3] The UN expects the world population to hit 9.8 billion by the mid-2050s. This has led to increased pressure on food resources, urging for increased farmland, and expanded agricultural sectors

worldwide. [4] Besides meeting the responsibility of providing food for the human population, agriculture is also crucial to economic growth, accounting for 4% of global gross domestic product (GDP). [4] In some developing countries, it can account for more than 25% of GDP. [6] Moreover, approximately 26.36% of the working population in the world is employed in the agricultural sector.

Under these circumstances, we must address this issue using modern, IOT-based technology. Currently, most countries rely on conventional mechanized farming, which presents various challenges. Key problems include dependence on fossil fuels, significant carbon emissions, high maintenance and repair costs, and health and safety concerns. To address these problems, we developed "Agrover." This innovative bot is designed to tackle these issues effectively.

[5] For example, pesticides account for approximately 3.2% of carcinogens worldwide. Farmers are often exposed to these harmful substances, increasing their risk of cancer significantly. Agrover mitigates this risk by utilizing its robotic arm to spray pesticides and insecticides, eliminating the need for physical contact with these chemicals. This protects farmers' health and enhances overall safety in agricultural practices.

Methodology

Team Atlas started the Agrover project by identifying the challenges faced by the agricultural industry, particularly those arising from conventional mechanized farming. Our team conducted several brainstorming sessions to gather ideas and develop solutions for these challenges.

We addressed the problems by designing a prototype of the Agrover robot. Every aspect of the robot—its components, features, and functions—was carefully thought through. We

paid particular attention to how each part would contribute to solving the specific issues we had identified, such as the inefficiency of traditional farming equipment, health risks from pesticide and insecticide exposure, and the need for precision in agricultural tasks. Once we finalized the objectives, we used Fusion 360 to create a 3D model of the robot, which allowed us to visualize how all the components would work together.

Figure 1: 3D Model of Agrover **Figure 2: 3D Model of the Seed Dispenser**

We employed the following features in the Agrover: 2 sprayers for the precise application of pesticides and fertilizers, a seeder for planting, a plougher for ploughing, and a driller for soil preparation. In addition, we integrated real-time data-capturing sensors, including the DHT11 for humidity and temperature measurement, a camera, a temperature sensor, and the SN-Moisture-MOD for monitoring soil moisture levels. These sensors provide real-time data, allowing the robot to adapt its functions based on real-time environmental conditions, optimizing resource usage and crop health.

After completing the 3D model, we selected the appropriate construction materials. After considering several options for the frame and wheels, we used steel due to its strength, durability, and resistance to wear and tear in challenging agricultural environments. Steel was used for the frame, arms, and wheels, ensuring that Agrover could withstand continuous fieldwork. After implementing the necessary materials, we assembled all the components, sensors, and functions.

Throughout the process, we faced several technical obstacles, including voltage regulation issues that affected power distribution, circuit burns caused by overloads, signal malfunctions in the robotic arm, and spray mechanism failures. We systematically addressed each issue and resolved the technical faults within two weeks. These challenges strengthened our understanding of the system and improved the overall functionality of the Agrover robot.

In addition to Agrover's ground-based capabilities, we decided to incorporate drones into the project further to enhance the efficiency and productivity of farming operations. Drones have become a game-changing tool in modern agriculture because they provide comprehensive airborne surveillance. With drones, we can monitor vast farmland areas in real-time, enabling us to assess crop health, identify early signs of disease or pest infestation, and detect areas requiring additional attention.

Additionally, we have incorporated a solar panel into Agrover, which can charge the system's battery by 70-80%. This solar panel works with a lithium-ion battery, one of today's most efficient battery technologies. Therefore, Agrover operates without using fossil fuels, resulting in zero carbon emissions.

Drones also offer the advantage of precise pesticide and fertilizer application. Integrating aerial technology with Agrover's land-based functions ensures that pesticides and fertilizers are applied only where needed, reducing waste and minimizing environmental impact. Moreover, drones are invaluable for field mapping, helping farmers to create detailed maps of their land. These maps allow for better decision-making regarding resource allocation, irrigation planning, and overall farm management. The combination of Agrover and drone

technology provides a seamless and integrated solution for modern smart farming, addressing essential sustainability and efficiency concerns in agriculture.

For this research, we decided to test-run the moisture sensor, one of the many sensors added to the Agrover. We collected a single day's data from a field, a hybrid tomato-pepper farm, in Demra, Dhaka, Bangladesh, from 6:30 am UTC+6 to 4:30 pm UTC+6. The 8-bit value of the moisture sensor was recorded every minute for ten continuous hours, and later, the 8-bit value was converted to moisture content in percentage. Using the data collected, we used Python code to produce a graph of moisture content against time to understand the pattern of changes in moisture content throughout the day. Using the moisture content values, we can also understand the pattern of changes in the strength of sunlight throughout the day.

Data Analysis

As mentioned above, the data structure and collection process are consistent across all sensors, making it unnecessary to include data from each sensor. Therefore, we chose to focus solely on testing the moisture sensor. The table below shows the value for time (given in the 24-hour format), the bit data (8-bit), and moisture content (given in percentage).

On the 8-bit scale, 100 represents arid soil with a moisture content of 0%, while 1024 represents an area wholly submerged in water with a moisture content of 100%. In the table, we omitted the values where data remained roughly constant.

The moisture content was calculated from 8-bit data using the following formula:

Moisture Content (in %) = [(Bit-Data – 100)/924] * 100

Time	Bit-Data	Moisture Content (%)
6:30	1024	100
6:31	694	64.29
6:36	698	64.72
6:40	729	68.07
6:49	779	73.48
7:10	825	79.22
8:12	832	79.22
8:51	827	78.35
9:37	820	77.6
10:06	810	76.84
10:53	763	71.75
11:13	752	70.56
11:58	733	68.51
12:33	707	65.69
13:03	675	62.23
13:32	632	57.58
14:15	595	53.57
14:23	584	52.38
15:05	579	51.84
15:30	573	51.19
15:58	569	50.76
16:12	567	50.54

The data on soil moisture content can be divided into four distinct phases: Initial Increase, Steady Level, Rapid Decrease, and Gradual Decline. The first recorded value at 6:30 AM was an outlier due to the initial sensor calibration, showing a value of 1024 (100% moisture), which has been excluded from the graph for accuracy. Farmers began watering the soil at 6:30 AM. From 6:31 to 8:12, moisture levels rose significantly from 64.29% to 79.22%. This increase occurred as the soil absorbed the water. The early morning sun was not intense enough to cause significant evaporation, allowing the soil to retain more moisture. During this period, moisture content remained relatively constant, fluctuating between 78.35% and 76.84%. The sunlight was moderate, and evaporation was minimal, balancing water absorption and loss. This phase reflects a stable state of moisture content as the soil approaches saturation. As the day progressed, stronger sunlight increased evaporation rates. Moisture content dropped significantly, from 76.84% at 10:06 to 52.38% by 2:23 PM. The intense sunlight led to rapid water loss from the soil, resulting in a steep decline in moisture. In the late afternoon, sunlight decreased, leading to a slower evaporation rate. Between 2:23 and 4:12 PM, moisture content gradually reduced from 52.38% to 50.54%. This slower decline reflects conditions similar to phase 2, where moderate sunlight caused less evaporation.

Figure 3: Table of Data

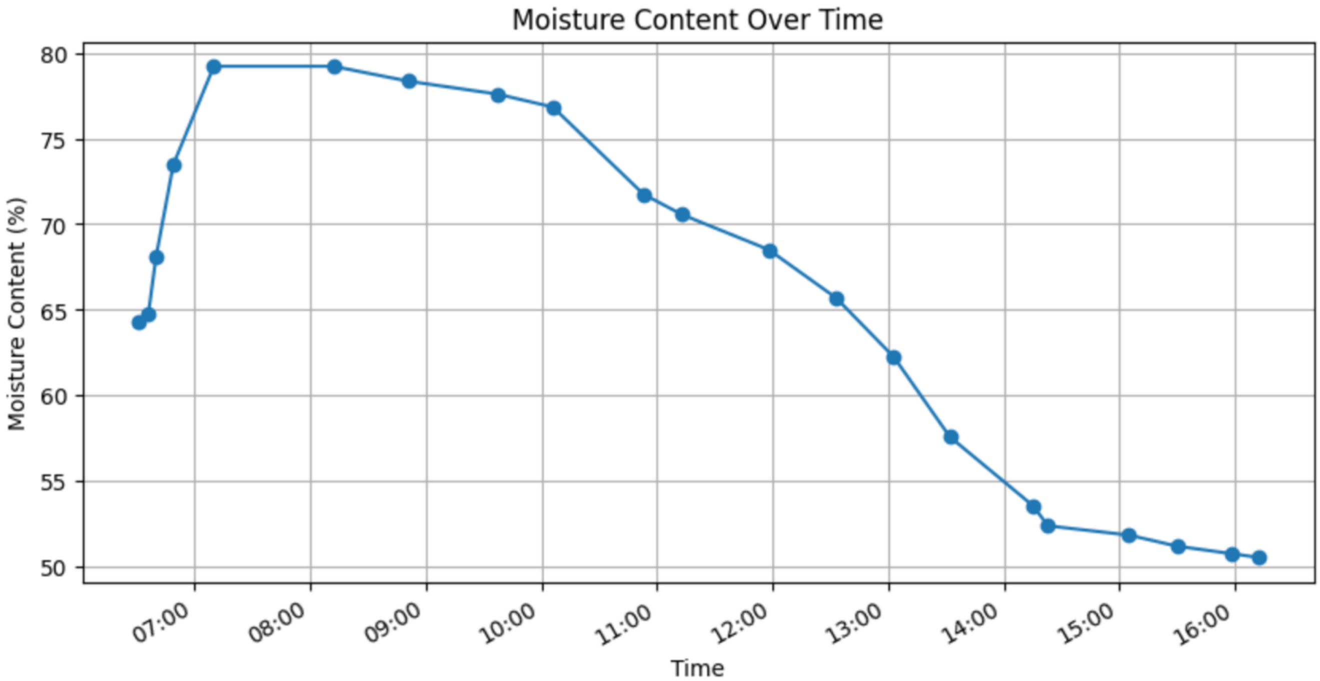

Figure 4: Graph of Moisture Content against Time

Conclusion

The Agrover project is an approach to modern agriculture that integrates robotics and IoT technologies to address critical agricultural and environmental challenges. By enhancing operational efficiency and minimizing health risks associated with pesticide exposure, Agrover improves productivity and prioritizes environmental sustainability through solar energy and lithium-ion batteries, resulting in zero carbon emissions. The analysis of moisture sensor data underscores the significance of real-time monitoring for optimizing irrigation practices and soil health management. Also, it shows that similar data for various sensors can be collected and analyzed. Furthermore, including drones for comprehensive crop surveillance enhances resource allocation and pest management decision-making. As the global population rises, Agrover is a model for how technological innovations can effectively support food security while promoting sustainable agricultural practices. This research highlights the potential for smart farming solutions to improve the agricultural sector, making it safer, more efficient, and environmentally responsible.

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