Course: CSE407 Green Computing

Section 02

“Term Project Proposal: Enhancing Sustainable Agriculture with IoT and Machine Learning for Energy and CO2 Reduction”

Submitted to:

Ahmed Abdal Shafi Rasel

Lecturer

Department of Computer Science & Engineering East West University, Dhaka

Submitted by:

Mahmudul Islam Bhuiyan

2022-3-60-219

Rajon Das

2022-1-60-050

Jannatul Ferdous

2022-1-60-056

Department of Computer Science & Engineering

East West University, Dhaka

1. Introduction

Agriculture is an indispensable pillar for food production worldwide, but at the same time, it is among those producing the most pollution, contributing to about 23% of worldwide GHG emissions. The conventional mode of agriculture enhances this environmental impact because of the inefficient use of resources such as water, energy, and soil. Most of the conventional agricultural systems also lack transparency and are usually very wasteful, failing to meet the changing environmental conditions. It is these inefficiencies, coupled with a lack of real-time monitoring systems and automated mechanisms for control, that stand in the way of devising more viable and resilient forms of agriculture.

In recent times, green computing and sustainable agriculture have been of great interest in many research activities since their goal is to reduce environmental impacts, while increasing efficiency in food production. This can promise a path toward smarter and more sustainable farming systems by integrating IoT technologies along with ML models and renewable energy solutions. This study presents a holistic system which integrates IoT-based sensors for real-time data collection, image processing-based crop growth monitoring, and renewable-powered DAC systems to reduce carbon emissions. This work aims at optimizing farming practices by reducing energy consumption and contributing toward carbon capture to further advance global goals pertaining to sustainability and climate action.

2. Research Problem

Agriculture is one of the most significant contributors to greenhouse gas emissions worldwide, while inefficient resource use is considered one of the top factors contributing to environmental degradation. Most of the conventional farming relies on manual methods, lacks monitoring of real-time data, and uses no advanced control systems, which make these farming practices inefficient and less adaptive to changes in environmental conditions. These lacunas in the existing systems retard the march toward achieving sustainable farming, which is vital for both food security and climate mitigation.

The research seeks to respond to such issues by integrating IoT-based sensors, image processing for crop growth monitoring, and renewable energy-powered DAC systems into a single unified farming system. This can be viewed as an approach to optimize resource utilization, bring down energy consumption, and raise carbon capture to make farming more eco-friendly.

3. Aim of the Study

The main objective of the research is to study the feasibility and performance of integrating IoT sensors, image processing, and DAC systems into one workable model for agriculture that consumes the least amount of energy, generates lower CO2 emissions, uses resources optimally, and ensures optimum growth of crops.

4. Objectives

The objectives of this research are as follows.

1. To design and implement an IoT-based monitoring system that will collect real-time data of temperature, humidity, water level, and soil condition in a controlled farming environment.

2. The idea is to apply machine learning models, particularly logistic regression, to predict and optimize farming actuators' operations-like fans and water pumps-using real-time data from IoT sensors.

3. To integrate renewable energy-powered DAC systems with the farming setup and evaluate their potential for CO2 capture, with the aim of achieving negative carbon emissions.

4. To gauge the energy savings and improvement in farming conditions, such as temperature and humidity, achieved through optimizations involving IoT and machine learning.

5. 5. Assess the scalability and feasibility of the proposed system for small- to medium-sized farms to make sure that it will be accessible and effective across a variety of agricultural scenarios.

5. Proposed Methodology

This study will adopt a blended approach of simulation-based methods and data collection in the real world to determine how effectively the system functions. The methodology will be as follows:

System Design:

IoT System: IoT sensors for temperature, humidity, and water level, together with cameras for image processing, shall be installed in a controlled agricultural setup for real-time monitoring and control of farm conditions.

DAC System: Renewable energy-powered DAC systems will be integrated into the farming setup for capturing CO2 emissions from the atmosphere and reducing the carbon footprint.

Data Collection:

IoT Sensors: During a period of six weeks, real-time data should be gathered on environmental factors, such as temperature, humidity, and water levels, to train machine learning models and fine-tune actuator functions.

Image Processing: Cameras and image processing algorithms will be used to analyze plant growth stages and detect any stress factors due to disease or water deficiency.

Energy Data: Energy usage data from farm operations will be monitored, such as pumps and fans, to calculate energy savings post-optimization.

Machine Learning:

The proposed work will implement logistic regression models; these models are trained on historical data to predict the activation time for actuators-fans and pumps-to optimize energy use while keeping plants within the best growth conditions. It will use cross-validation to ensure that the model generalizes well and does not overfit, hence having a variance in the predictions.

CO2 Capture Simulation:

Its performance in capturing CO2 will be simulated using benchmarking from previous studies to estimate its potential effectiveness for a farm area of 150 hectares.

Expected energy savings and CO2 capture will be modeled by integrating logistic regression outputs with DAC systems.

6. Tools and Technologies

The following tools and technologies will be employed in the study:

IoT Sensors: Wemos D1 for data transmission, RFID tags for tracking temperature, humidity, and soil conditions.

2. Machine Learning: Scikit-learn shall be used for training the logistic regression models that can predict actuator operations.

3. Simulation Platform: Python with its libraries, such as Pandas, NumPy, and Scikit-learn, will be employed for data processing, model development, and result analysis.

4. DAC System: Integration of renewable energy sources like solar panels, wind turbines, and microalgae to operate the capture of CO2 by the DAC systems.

5. Data Analysis: Python will be used for data preprocessing, model training, and visualization of results.

7. Similar Type of Work Done

Various researchers have worked on integrating IoT, image processing, and machine learning into agriculture to make it more sustainable. For example:

For instance, Luyu et al. introduced in 2010 an IoT sensor-based system for green agricultural products to enhance market efficiency and reduce waste.
Tran et al. (2018) implemented an integrated system for IoT and image processing for monitoring plant growth, recording higher seed germination rates.
Qiu et al. (2022) developed a renewable energy-powered, DAC-driven CO2 reduction system that could achieve a CO2 reduction of 752 tons per year on a 150-hectare farm.

These works illustrate how IoT, machine learning, and renewable energy together can be useful in agriculture. However, none of these works have integrated all three elements of IoT, machine learning, and DAC systems into a single cohesive and scalable solution that can be used on small- to medium-sized farms. This paper addresses this lacuna by presenting the design of an efficient and cost-effective system that would assist in optimizing farming practices, both to minimize environmental impact and enhance productivity.

8. Expected Results

Expected outcomes from the research include

1. Energy Savings: Optimization by IoT sensors and machine learning is likely to achieve a 9.1% reduction in energy use through the optimization of actuators.

2. Better Conditions for Growth: It is anticipated that the enhanced conditions of the environment will boost the growth of the plants by 20%.

3. CO2 Capture: Renewable-powered DAC systems are projected to capture approximately 753 tons of CO2 per year on a medium-sized farm.

4. Scalability: The system will show that it is scalable and hence appropriate for small and medium-sized farms.

Therefore, in this study, a sustainable agricultural model will be developed by integrating real-time monitoring with resource optimization and carbon-capture technologies that would create a greener, more efficient farming system.

Conclusion

This research work will promote an integrated approach to sustainable farming with the help of different advanced technologies: IoT-based monitoring systems, machine learning models, and renewable-powered Direct Air Capture systems. The study will develop an integrated farming system addressing major issues in resource utilization, energy losses, and carbon dioxide emissions that is environmentally and economically feasible. Expected outcomes of this research-energy efficiency, enhanced growing conditions, capture of CO2, and scalability-have revolutionary consequences for farming, hence assisting the global effort toward sustainability. Beyond this, such research also aids in understanding the practical implications of the technologies through a scalable model for small- to medium-sized farms.

References

- **Miller, T., et al. (2025).** The IoT and AI in agriculture: The time is now—A systematic review of smart sensing technologies. *Sensors, 25*(12), 3583.
- **Quispe Vilca, J. L., et al. (2024).** Integrating IoT and image processing for crop monitoring. *Electronics, 13*(24), 4863.
- **Satav, P. R. (2022).** IoT and machine learning for real-time crop monitoring and management. *International Journal of Food and Nutritional Sciences, 11*(2).
- **Luyu, X., Xuemei, L., Jian, Z., & Yuning, X. (2010).** Research on the innovation of strategic business model in green agricultural products based on Internet of Things (IoT). In *2010 International Conference on E-Business and E-Government*.
- **Tran, H. A. M., Ngo, H. Q. T., Nguyen, T. P., & Nguyen, H. (2018).** Design of green agriculture system using Internet of Things and image processing techniques. In *2018 4th International Conference on Green Technology and Sustainable Development*.
- **Qiu, J., Yang, L., Chen, X., & Wu, X. (2022).** Optimal configuration of a negative carbon emission energy system for green agriculture. *IFAC-PapersOnLine, 55*(9), 501–506.
- **Ayaz, M., & Kiani, M. (2024).** The role of IoT in driving smart farming. *Sensors Journal.*