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IoT-Based Environmental Monitoring in a Sawtooth Greenhouse: Foundations for CFD, Anomaly Detection, and Environmental Prediction

The global agriculture sector faces mounting challenges due to climate change, rising atmospheric CO_2 levels, and increasing food demand from growing urban populations. Greenhouses have emerged as vital solutions to ensure improved food production. In earlier work, a real-time Internet of Things (IoT) sensor network was deployed in a sawtooth-shaped greenhouse to monitor temperature and humidity distributions. This provided key insights into the microclimate and laid the groundwork for future integration with computational fluid dynamics (CFD) simulations, aimed at optimizing natural ventilation, energy use, and environmental control.

Expanding on that framework, this study implements an enhanced IoT-based sensing network in a greenhouse, monitoring temperature, humidity, CO_2 equivalence (CO_2eq), and total volatile organic compounds (tVOC) across nine spatially distributed locations grouped into three zones (high-irradiation vent, middle, and far end). Over a 50-day period, a statistical filtering algorithm was used to remove sensor noise and quantify uncertainty, ensuring high data integrity from these locations. Results showed elevated temperatures and poor air quality (high CO_2eq and tVOC) at the high solar radiation vent, while the middle and far-end zones exhibited more favorable conditions due to high ventilation.

This dataset offers a valuable foundation for future CFD studies by providing detailed spatial and temporal environmental insights essential for model validation and simulation benchmarking. This is the basis for a digital twin that can be used to optimise crop yield growth and updated by real-time sensor data. Additionally, the high-resolution data and established patterns open new avenues for anomaly detection and predictive modeling of environmental conditions within greenhouses. These capabilities are critical for developing intelligent climate control strategies and advancing precision agriculture technologies for an increase in crop production.

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