

AI-DRIVEN GREENHOUSE MANAGEMENT: OPPORTUNITIES AND CHALLENGES IN AUTOMATION

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Анотація

Ця робота досліджує інтеграцію штучного інтелекту (ШІ) в управління теплицями, розглядаючи критичні сільськогосподарські виклики, такі як обмеженість земель та продовольча безпека. ШІ підвищує точність контролю, збільшуючи врожайність та оптимізуючи ресурси, але стикається з перешкодами під час криз, прикладом чого є війна в Україні, включаючи залежність від інтернету та ризики форс-мажорних обставин. Аналізуючи рішення на основі ШІ, такі як LUNA, AgroFlow та Heliospectra, дослідження підкреслює їхні переваги у моніторингу в реальному часі та оптимізації ресурсів, водночас визнаючи обмеження підключення. Запропоновані рішення включають локальну обробку та резервні системи. Зрештою, автоматизація теплиць на основі ШІ значно зміцнює стійкість сільського господарства та стабільність виробництва продуктів харчування, особливо під час криз.

Ключові слова: штучний інтелект, автоматизація теплиць, сільське господарство, розумне фермерство, Інтернет речей (IoT).

Abstract

This paper examines the integration of artificial intelligence (AI) into greenhouse management, addressing critical agricultural challenges like limited land and food security. AI enhances precision control, boosting yields and optimizing resources, but faces obstacles during crises, exemplified by the war in Ukraine, including internet dependency and force majeure risks. Analyzing AI-driven solutions like LUNA, AgroFlow, and Heliospectra, the study highlights their benefits in real-time monitoring and resource optimization, while acknowledging connectivity limitations. Proposed solutions include local processing and backup systems.¹ Ultimately, AI-driven greenhouse automation significantly strengthens agricultural resilience and food production stability, particularly during crises.

Keywords: Artificial Intelligence, greenhouse automation, agriculture, smart farming, IoT.

Introduction

The rapid evolution of artificial intelligence has revolutionized various industries, including agriculture. With the global population continuously growing, sustainable and efficient food production has become a crucial issue. Traditional Farming methods struggle to meet increasing food demands due to environmental challenges such as climate change, water scarcity, and soil degradation. AI-based solutions offer a new era of precision farming, enabling greenhouse operators to maximize efficiency while minimizing resource waste.

Greenhouses provide a controlled environment for crop cultivation, reducing dependence on unpredictable weather conditions. However, maintaining optimal conditions requires constant monitoring and adjustment. AI-driven greenhouse automation addresses this need by integrating IoT (Internet of Things) devices, sensors, and machine learning algorithms to regulate lighting, humidity, temperature, and soil conditions in real time.

The purpose of this research is to analyze AI-based greenhouse management solutions, identify their advantages, and highlight the challenges associated with their implementation. [1]

Research Results AI in Greenhouse Management

Artificial intelligence significantly enhances greenhouse efficiency by enabling real-time data collection and intelligent decision-making. Several AI-driven solutions have been developed to optimize greenhouse management:

1. LUNA by iUNU: Uses computer vision for real-time plant condition monitoring, allowing automated adjustments to environmental factors.
2. AgroFlow: Focuses on optimizing irrigation systems and monitoring soil conditions.
3. Heliospectra: Specializes in intelligent LED lighting systems to enhance plant photosynthesis, increasing crop yields by 15-30%.

These AI-powered technologies contribute to resource efficiency by reducing water, fertilizer, and energy consumption. [2], [3]

Challenges of AI-driven Greenhouses

Despite its benefits, AI-driven greenhouse automation faces multiple challenges, particularly in Ukraine, where the war has disrupted technological infrastructure. The key obstacles include:

1. Dependence on internet connectivity: Many AI systems rely on cloud computing, making them vulnerable to connectivity issues.
2. Risk of crop failure: Unexpected events, such as power outages or cyber attacks, can disrupt automated systems.
3. High implementation costs: AI integration requires significant initial investment in hardware, software, and maintenance.

To mitigate these risks, researchers propose solutions such as:

1. Implementing local AI processing to reduce dependence on cloud services.
2. Using backup power sources and alternative internet connectivity (e.g., satellite networks).
3. Dividing greenhouse power supply into zones to prevent complete system failure. [4]

IoT and AI Integration in Smart Greenhouses

The increasing popularity of IoT devices in agriculture plays a key role in developing AI-driven greenhouses. According to recent studies, the global agricultural IoT market is expected to reach \$18.7 billion by 2026, with a projected annual growth rate of 8.8%. [5], [6]

One example of AI and IoT integration is Dusun IoT, a company providing smart greenhouse solutions. Their DSGW-030 IoT Gateway enables real-time monitoring and control of greenhouse conditions using Bluetooth 5.3 technology. Key features include:

1. Real-time monitoring: Sensors collect and analyse data on temperature, humidity, light intensity, and soil moisture, ensuring optimal growth conditions.
2. Automated lighting control: AI-powered LED lighting adjusts light intensity and spectrum to meet different plant growth stages.
3. Intelligent irrigation: Automated control of water supply prevents under- or over-irrigation, improving water efficiency.
4. Remote management: Farmers can monitor and control greenhouse conditions via a mobile app or voice commands.

These AI-driven solutions improve agricultural productivity and reduce operational costs, making smart greenhouses a promising approach for the future of farming. [6]

Conclusion

The adoption of artificial intelligence in greenhouse management marks a new era of smart agriculture, improving productivity, resource efficiency, and sustainability. AI-driven solutions enable real-time monitoring, intelligent automation, and precision control, resulting in higher yields and reduced waste. However, challenges such as reliance on internet connectivity, high implementation costs, and risks of system failures must be addressed.

Future developments in AI and IoT are expected to enhance greenhouse automation, ensuring food security and sustainable agricultural practices. In the coming years, AI-driven smart greenhouses will play a crucial role in addressing global food production challenges while adapting to climate change and geopolitical uncertainties.

By integrating AI-based solutions, the agricultural industry can build a more resilient and efficient farming ecosystem, paving the way for the future of smart agriculture. [7]

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