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Research on Tomato Quality Prediction and Fish Disease Diagnosis Based on Multimodal Data

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Abstract. We propose a multimodal data-driven scheme for intelligent tomato quality prediction and fish disease diagnosis to advance smart protected agriculture and modern aquaculture. Integrating multi-source environmental, visual and managerial data, we construct a full-cycle tomato dataset and develop AI prediction and decision models to address the insufficient digitization and experience-dependent management in traditional tomato cultivation. Targeting aquaculture complexity, this work builds a intelligent monitoring system combining underwater robots, multimodal large models and professional knowledge bases. A lightweight detection model integrated with Retrieval-Augmented Generation mitigates model hallucinations and improves diagnostic credibility, while optimized underwater communication protocols guarantee stable data transmission in complex water environments. This study also realizes cross-scenario technology migration from terrestrial planting to aquaculture, achieving accurate, low-cost underwater perception and advanced fish disease early warning. The proposed solutions provide effective technical support for agricultural and aquacultural intelligent upgrading.

Keywords: Protected tomato; Fish Disease Diagnosis; AI agent; Multimodal data.

1. Introduction

Facility planting and aquaculture are pivotal pillar industries of modern agriculture, underpinning agricultural product supply and rural economic growth. As a high-value cash crop, tomatoes occupy a core position in facility agriculture, yet the industry suffers from short industrial chains, low digital penetration, and heavy reliance on empirical manual management. Traditional tomato planting is constrained by inefficient field management, excessive agrochemical waste, and unstable fruit quality, lacking data-driven precise regulation and intelligent decision support.

Similarly, the aquaculture industry faces extensive management, backward monitoring technologies, and delayed risk early warning. Complex underwater environments characterized by turbid water and strong disturbances result in low-precision data perception, high transmission delay and packet loss. Moreover, conventional breeding depends heavily on empirical judgment, while existing intelligent models suffer from diagnostic inaccuracies and large model hallucinations, easily causing unanticipated aquaculture losses.

Current agricultural intelligent research is mostly limited to single scenarios, with insufficient exploration of cross-scenario technical migration between terrestrial planting and underwater aquaculture. Mature digital monitoring and AI decision-making technologies in facility planting have great potential to empower aquaculture, but relevant theoretical and practical research remains scarce.

Against this backdrop, this paper proposes a cross-scenario intelligent agricultural scheme based on multimodal data fusion. It integrates tomato quality prediction and intelligent aquaculture monitoring, constructing a dual-scenario AI decision-making system. Beyond establishing a full-cycle tomato multimodal dataset and precise planting prediction model, this study innovatively develops an underwater robot multimodal large model-knowledge base integrated aquaculture monitoring system. Through lightweight algorithm optimization, adaptive network protocol improvement and land-water technical migration, this work resolves empirical management bottlenecks in both industries, providing technical support for agricultural digital and intelligent transformation.

2. Related Work

Global research on intelligent facility planting and aquaculture has yielded preliminary achievements [1]. Developed countries have formed mature digital tomato planting systems: Israel adopts automatic irrigation and precision fertilization for whole-process environmental control; the Netherlands utilizes greenhouse fine control and vertical agriculture to boost planting efficiency; American agritech platforms realize tomato growth monitoring and pest early warning. In agricultural big data research, scholars have applied WebGIS [2], GEE cloud platforms [3] and data warehouse technologies to construct agricultural data systems [4] and support macroscopic planting decisions [5]. In aquaculture intelligence, existing studies mainly focus on single water quality monitoring and simple visual identification [6]. Preliminary optimizations of underwater sensor transmission and machine learning-based water quality evaluation have been realized [7], but most methods adapt only to simple water environments.

Domestic studies have achieved progress in tomato digital planting and aquaculture informatization. Existing tomato models can realize basic growth and quality prediction, while aquaculture research is confined to single-indicator monitoring, lacking multimodal data fusion. Critically, current aquaculture intelligent models have prominent hallucination problems with low diagnostic accuracy, and traditional transmission protocols fail to adapt to complex aquaculture water bodies. Most importantly, cross-scenario technical migration between facility planting and aquaculture is rarely studied, restricting the iterative upgrading and large-scale application of agricultural intelligent technologies.

In summary, existing studies have laid a foundational framework but have obvious deficiencies: single-scenario research dominates, aquaculture intelligent diagnosis accuracy is insufficient, underwater data transmission stability is poor, and cross-industry technical empowerment mechanisms are absent. This paper innovates cross-scenario multimodal intelligent agricultural research to fill these research gaps.

3. Research Content and Technical Scheme

This study targets the dual intelligent upgrading demands of facility tomato planting and modern aquaculture. It constructs cross-scenario multimodal datasets, breaks through core intelligent technologies, builds optimized algorithm models and integrated platforms, and verifies engineering applications to realize quality improvement and efficiency enhancement in both agricultural sectors.

3.1. Expected Research Objectives

Four core research objectives are formulated in this study. First, construct a full-growth-cycle high-quality multimodal dataset for facility tomatoes to support model training and planting decision optimization. Second, establish a TB-level multimodal fishery dataset covering multiple fish species and develop a dedicated aquaculture diagnosis large model to achieve professional and accurate breeding risk early warning. Third, break through three key technologies including lightweight fishery perception fusion, adaptive underwater transmission protocol, and land-water cross-scenario technical migration. Fourth, complete on-site deployment and engineering verification of the aquaculture intelligent system, optimize the tomato management platform, and form a replicable land-water integrated intelligent agricultural mode to replace traditional empirical management.

3.2. Multi-Scenario multimodal Data Collection Scheme

This paper builds a complete cross-scenario agricultural multimodal dataset covering facility tomato planting and aquaculture scenarios. For tomato planting scenarios, 200 monitoring points are deployed to collect greenhouse environment, soil physicochemical, crop growth visual, and field management data throughout the growth cycle. High-precision monitors capture tomato morphological changes hourly, while manual and mini-program collaborative recording collects daily field operation data. Regular soil detection and yield-quality correlation statistics are conducted to form a standardized tomato planting dataset.

For aquaculture scenarios, an underwater robot and multi-sensor fusion system is adopted for full-dimensional data collection. Multi-parameter sensors acquire real-time water temperature, pH, dissolved oxygen and other water quality indicators. Underwater high-definition equipment captures fish growth posture, lesion characteristics and water turbidity images across breeding cycles. Combined with breeding management logs and historical disease data, a standardized TB-level multimodal fishery dataset is constructed for model optimization.

3.3. Core Key Technology Research

3.3.1. Lightweight Perception and Large Model Fusion Technology.

Aiming at turbid and low-visibility underwater environments, this study designs a lightweight embedded biological detection model with image defogging and turbidity removal preprocessing to improve feature extraction accuracy under low computing power. Combined with Retrieval-Augmented Generation (RAG) technology and a self-built professional aquaculture knowledge base, a standardized large model reasoning link is constructed. This approach effectively eliminates large model hallucinations, significantly improving the professionalism and accuracy of fish disease diagnosis and water quality assessment.

3.3.2. Environment Adaptive Underwater Wireless Transmission Protocol Optimization.

To address high delay, packet loss and energy consumption in complex aquaculture water bodies, this study optimizes traditional underwater MAC and routing mechanisms. A water environment adaptive MAC protocol and cross-layer geographic auxiliary routing protocol are developed to dynamically adjust transmission frequency, power and node working status according to water turbulence and turbidity. This realizes stable collaborative monitoring and real-time back transmission of underwater multi-device data and high-definition images.

3.3.3. Land-Water Cross-Scenario Technology Migration Mode.

This study summarizes mature technical paths and promotion modes of facility planting intelligent technologies including soil moisture monitoring and water-fertilizer integration. By analyzing the common logic of multimodal perception and intelligent decision-making in planting and aquaculture scenarios, it realizes the reverse empowerment of terrestrial planting technologies for aquaculture intelligence, optimizing heterogeneous scenario adaptability and forming a universal cross-scenario agricultural technical system.

3.4. Core Model Algorithm Construction

Two sets of core intelligent algorithm models are constructed for dual scenarios. The tomato intelligent management and quality prediction model fuses greenhouse environment, soil, growth vision and management log data. It builds a tomato AI expert agent to realize environmental diagnosis, pest early warning, personalized water-fertilizer scheduling, and accurate prediction of tomato yield and quality, enabling data-driven fine planting management.

The fishery intelligent diagnosis and early warning model takes underwater vision, multi-dimensional water quality and breeding management data as inputs. Based on lightweight perception and RAG-enhanced large models, it achieves real-time water quality evaluation and fish disease diagnosis, realizing 3–5 days advance early warning of breeding risks. The model effectively solves the problem of passive risk response in traditional aquaculture.

4. Platform Design and Technology Application

This paper develops an integrated land-water intelligent agricultural management platform based on IoT, big data and AI technologies, realizing full-process digital monitoring and intelligent decision-making for planting and aquaculture.

4.1. Platform Research and Development Content

The platform consists of two core functional modules and one cross-scenario sharing module. The tomato quality intelligent management module integrates environmental monitoring, growth analysis, quality prediction and intelligent decision-making functions, supporting visual planting data display and whole-cycle standardized planting scheme generation.

The aquaculture intelligent monitoring module relies on underwater robot perception and large model diagnosis to realize real-time water quality monitoring, fish growth and disease identification, and risk early warning, automatically generating precise breeding regulation schemes. The cross-scenario data sharing and technology migration module supports mutual iteration and complementary optimization of dual-scenario intelligent technologies.

4.2. Engineering Application and Promotion

The aquaculture intelligent system is deployed and verified in large-scale breeding bases, while the tomato management platform is iteratively optimized in facility planting bases. Through on-site demonstration and technical training, the digital operation capability of agricultural practitioners is improved. Mature planting technology promotion modes are applied to aquaculture scenario popularization, realizing the transformation of laboratory achievements into engineering practical technologies, and verifying the industrial adaptability and application value of the system.

5. Summary

This paper proposes a multimodal data-driven intelligent decision-making scheme integrating tomato quality prediction and aquaculture monitoring, solving the empirical management and low-digitalization pain points in traditional planting and aquaculture industries. In terms of facility planting, a full-cycle tomato multimodal dataset and AI decision-making model are constructed to achieve precise planting regulation and quality prediction. In aquaculture research, an integrated underwater robot-large model-knowledge base monitoring system is developed, breaking through bottlenecks of low-precision underwater perception and unstable data transmission. The RAG-enhanced diagnosis model eliminates large model hallucinations and realizes advanced breeding risk early warning. Furthermore, this study explores a land-water cross-scenario technical migration mode, constructing a universal intelligent agricultural technical system with high scenario adaptability. Future research will expand monitoring crop and aquaculture species coverage, optimize algorithm accuracy and model generalization, improve platform functions, and promote large-scale application of the land-water integrated intelligent agricultural system. This research provides a solid technical foundation for the comprehensive intelligent transformation and sustainable high-quality development of modern agriculture.

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